Locomotive Valve Setting

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LOCOMOTIVE VALVE SETTING

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NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

LOCOMOTIVE VALVE SETTING

LOCOMOTIVE VALVE SETTING—(Continued)

LOCOMOTIVE VALVE SETTING

Serial 4001 Edition 3

ADJUSTMENT OF LOCOMOTIVE VALVE GEARS

INTRODUCTION

1. Definition.—*Valve setting* is a term generally applied to the work of making the final accurate adjustments to the valves and the valve gear of a locomotive before it is placed in service. These adjustments are made in order that the positions of the valves shall at all times bear their proper relation to the positions of the pistons. Valve setting follows the erection or hanging of the valve gear by the machinist.

2. Necessity for Corrections.—If every part of the locomotive were made and erected exactly as the designer intended, very few adjustments in the valve gear would be necessary, provided the designer has been careful and accurate in his work. Many errors creep into the construction, however, and though each error may be very small and perhaps unavoidable, their total effect will make some adjustment necessary when the valves are set.

Some of the common errors are as follows: The steam ports in the valve chests may not be equally spaced on each side of the vertical center line of the cylinders; if a piston valve is used, the valve bushings may be pushed or set in too far, or not quite far enough; the tapered end of the valve stem may have gone $\frac{1}{64}$ inch or so too deep or not quite deep enough into its socket. Perhaps the distance from the vertical center line

of the cylinder to the vertical center line of the main axle is not correct, or the eccentric may be a little out of its proper setting.

Valve setting is not merely a means of counteracting careless and inaccurate work, because some adjustment is always required, but the more accurate the work is before assembly, the smaller will be the necessary adjustments.

3. Object of Valve Setting.—The object of valve setting is to get as nearly as possible a perfectly square distribution of steam to the cylinders. This means that preadmission, cut-off, release, and closure take place at an equal distance from the beginning of the piston stroke at both the front and the back ports, and also that an equal lead and an equal full-port opening is obtained at the front and back ports. These ideal conditions would have to prevail in full forward gear, in full backward gear, and in all intermediate gears, and the right-hand valve would have to give the same readings as the left-hand valve in all positions of the reverse lever.

4. Requirements of Valve Gear.—A locomotive valve gear has to control the distribution of steam with great precision through a wide range of cut-offs in both the forward and reverse direction. The maximum cut-off is used to start the train, but after the train is under way, the cut-off is shortened and is varied from time to time by the reverse lever in order that the required draw-bar pull may be developed with the lowest possible consumption of steam. These features make the adjustment of locomotive valve gears an entirely different problem from that of the valve gears of other types of steam engines.

5. Importance of Correct Steam Distribution.—A perfect distribution of steam is practically impossible, but for economy it is necessary to get as close to perfection as possible, especially in the cut-off at which the locomotive is generally worked. A perfect exhaust is even more important than a perfect distribution of steam. A perfect distribution of steam would of course give a perfect exhaust, but, as the former is impossible, it is necessary to set the valves so that the

combination of valve events will give an exhaust of four perfectly even beats. The exhaust induces the draft needed to burn the fuel rapidly. The jets of steam from the exhaust pipe create a partial vacuum in the smokebox, and it is important that the vacuum be maintained as constant as possible, so that there may be an even flow of air through the fire.

If one exhaust is much stronger than the other three on account of the valves being out of square, the strong exhaust will pull holes in the fire and a part of the coal will be carried through the flues instead of being burned. With holes in the fire, too much air flows through these sections of the grates, thereby robbing the rest of the fire of some of the oxygen necessary to support rapid combustion; furthermore, the rush of cold air through the holes has a ruinous effect on the firebox.

To fire a locomotive with economy and also to have it steam freely, it is necessary to carry a light fire evenly spread over the grates. If the fire is heavy, black smoke is produced, and this means incomplete combustion. With the valves badly out of square, it is impossible to carry a light fire, as it will be pulled full of holes by the fierce intermittent draft.

6. A locomotive with the valves badly out of square wastes coal by throwing it out of the stack and also by incomplete burning of what is on the grates, owing to the heavier firing necessary. The wear and tear on the locomotive is greater, and pounds will develop more rapidly on account of the unequal work performed on the four strokes of the piston. The tractive effort is lessened, and the locomotive is much more liable to slip and stall in a pinch because of the unequal turning effect on the driving axle.

Accuracy in valve setting gives splendid returns. Instances are common where the correct setting of the valves has shown a saving in fuel of 2 or 3 tons per trip with a heavy locomotive.

It is poor economy to use slipshod methods in valve setting, and whatever work on the locomotive may be hurried through, the valves should be set with the greatest care. The cost of the few hours' extra work necessary to do this will be quickly repaid in the saving in fuel.

7. Care of Tools.—The tools used in valve setting should be kept in good condition. Trams, dividers, center punches, etc., should have their points hard and sharp, so that accurate work may be done.

A person engaged in setting valves should be patient and should not get discouraged if things do not come right the first or second attempt. He should also be on the lookout for troubles, and when these are encountered, he should be able to recognize them quickly.

SETTING VALVES WITH WALSCHAERT VALVE GEAR

GENERAL DESCRIPTION OF GEAR

8. Introduction.—On the modern American locomotive outside valve gears have almost entirely superseded the Stephenson gear; of the outside gears, the Walschaert is the most generally used. By an outside valve gear is meant one which has the majority of the working parts outside of the wheels instead of between the frames.

The advantages claimed for the Walschaert gear are that it is light in weight, very accessible for inspection and maintenance, low in maintenance cost, and when once correctly set will keep square from shopping to shopping. With the gear on the outside of the frames, there is nothing to interfere with the proper bracing of the frame at the main pedestals, and with the present-day heavy locomotives an efficient brace at this point is most essential.

9. Arrangement of Gear.—In Fig. 1 is shown the arrangement of a Walschaert valve gear as it is generally applied to a passenger locomotive, and Fig. 2 shows the same gear as applied to a freight locomotive. There is no difference in the gear itself, but, owing to the different wheel arrangement, a different method of attaching it to the main frames is necessary.

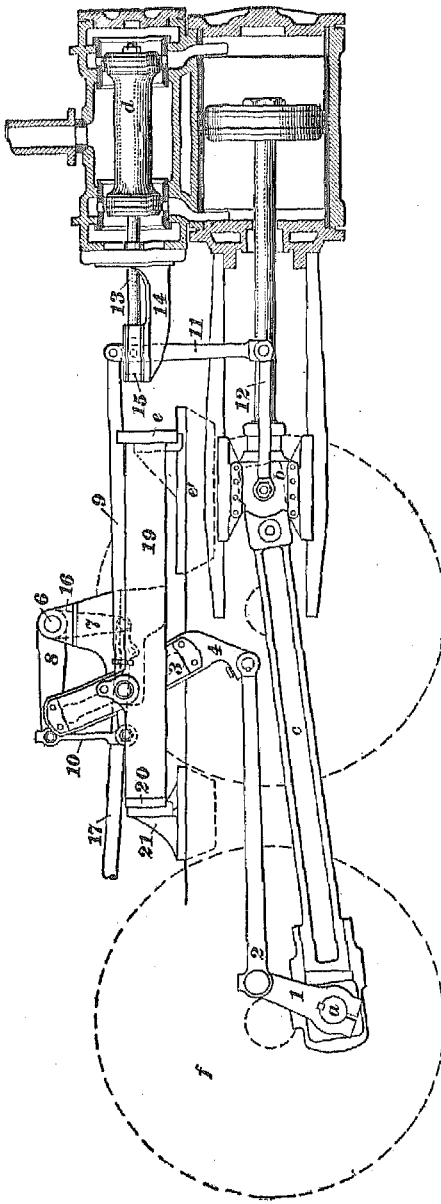

Fig. 1

On the passenger engine, Fig. 1, which always has a four-wheel engine truck, the guide yoke *e* is located ahead of the front driving wheels, but on the freight engine, Fig. 2, with a two-wheel engine truck, the front drivers are so close to the cylinders that the guide yoke has to be located between the first and second pairs of driving wheels. On this account the link *3* of the passenger engine is supported by a pair of frames *19* which are carried between the guide yoke *e* and the motion-support cross-tie *20*. This cross-tie is located between the first and second drivers, but on the freight engine the link is supported by a casting *16* which is bolted directly to the guide yoke *e* or sometimes cast integral with the guide yoke end.

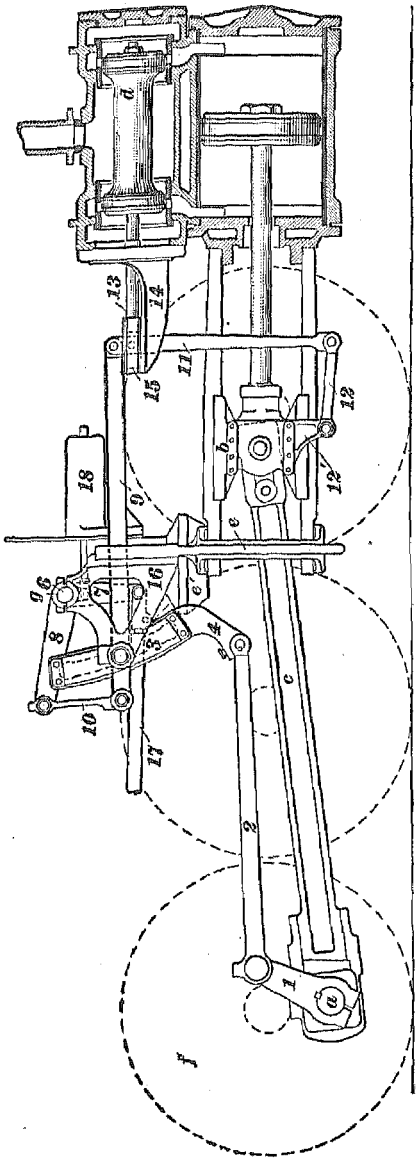

FIG. 2

10. Names of Parts.—Referring to Figs. 1 and 2, the names of the parts of the gear are as follows: *1*, the eccentric crank; *2*, the eccentric rod; *3*, the link with the link foot *4*; *6*, the reverse shaft; *7*, the reverse-shaft crank; *8*, the reverse-shaft arm; *9*, the radius rod; *10*, the radius-rod hanger; *11*, the combination or lap-and-lead lever; *12*, the union link; *12'*, Fig. 2, the crosshead arm; *13*, the valve stem; *14*, the valve-stem crosshead guide; *15*, the valve-stem crosshead; *16*, the link support; *17*, the reach rod; *18*, the counterbalance spring casing; *19*, Fig. 1, the link support frames; *20*, the motion-support cross-tie; *21*, motion-support cross-tie bracket. The main pin is marked *a*, the crosshead *b*, the main rod *c*, the valve *d*, the guide yoke *e*, the guide-yoke bracket *e'* and the main driving wheel *f*.

11. Sources of Valve Movement.—A study of Figs. 1 and 2 will show that the valve derives its motion from two distinct sources; first, from the main crosshead through the combination lever, and second, from the eccentric crank through the link. When either of these sources of motion is exerting its maximum influence on the displacement of the valve from its central position, the influence of the other source of motion is *nil*. When the piston is at the extreme end of the stroke, either front or back, the combination lever has its greatest effect on the valve, but the link at these points assumes a vertical position and, therefore, has no influence on the valve, no matter what the position of the reverse lever may be. When the piston is at half-stroke, the link has rocked over to its extreme position and the eccentric crank then exerts its maximum influence, but the combination lever is now vertical and has no effect whatever.

On this account each of these sources of motion may be considered separately without regard to the influence of the other when setting the valves, and this feature makes it fairly easy to get accurate results.

12. The motion which the valve derives from the combination lever is equal to twice the steam lap plus twice the lead, and this motion is not affected by the reverse gear in any way, but remains constant in all positions of the lever. The motion derived from the eccentric crank and transmitted through the link to the valve, is simply a symmetrical motion front and back of the central position. This motion is increased or decreased according to the distance of the link block from the center of the link. When the link block is exactly in the center of the link, there is no motion from this source, but the farther the link block is from the center, the greater will be the valve travel. The locomotive will be reversed if the link block is raised from the bottom to the top of the link, or vice versa. As the valve is always in the same position when the piston begins its stroke, and as the valve is only affected at this point by the crosshead through the combination lever, the lead with the Walschaert gear is constant.

The control of the cut-off is obtained by raising or lowering the radius rod, thereby increasing or decreasing the distance of the link block from the center of the link, and increasing or

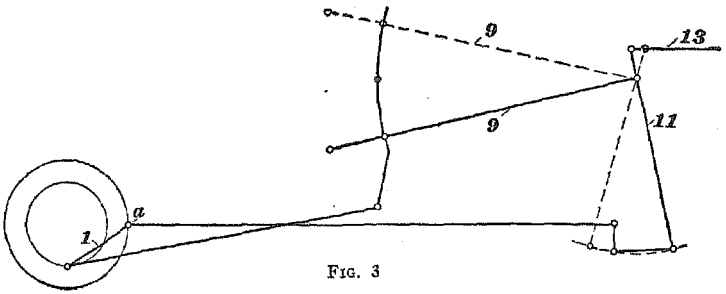

FIG. 3

decreasing the valve travel. This does not affect the lead in any way, but preadmission is increased slightly as the valve travel is shortened.

13. Direct and Indirect Motion.—The gears shown in Figs. 1 and 2 are arranged for inside-admission valves and direct motion, but when conditions require it, the Walschaert valve gear can be just as easily arranged for outside-admission valves or for indirect motion. *Direct motion* means that the

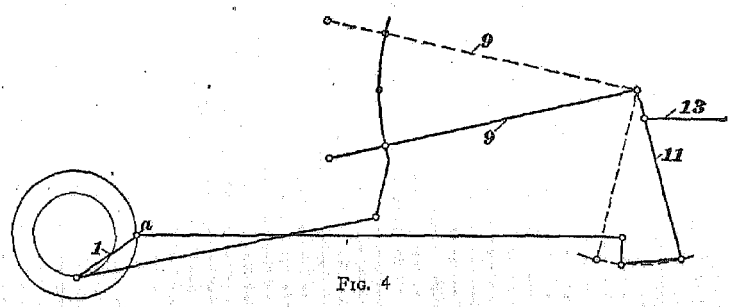

FIG. 4

valve moves in the same general direction in forward gear as the eccentric rod. *Indirect motion* means that the valve moves in the opposite direction to the eccentric rod. With direct motion, the link block is in the bottom of the link for forward gear, and with indirect motion the block is in the top

of the link in forward gear. In Fig. 3 is shown the arrangement used with outside-admission valves and direct motion. In this case the radius rod *9* is connected to the combination lever below where the valve stem *13* is connected to it, and the eccentric crank *1* leads the main crankpin *a*.

In Fig. 4 is illustrated the arrangement used with inside-admission valves and indirect motion. The radius rod *9* is connected to the combination lever *11* above the valve stem *13* and the eccentric crank *1* leads the main crankpin *a*.

In Fig. 5 is shown the arrangement used with outside-admission valves and indirect motion. The radius rod *9* is

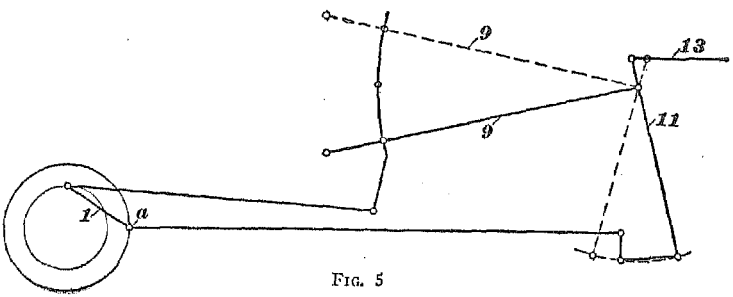

FIG. 5

connected to the combination lever *11* below the valve-stem *13*, and the eccentric crank follows the main crankpin. The position of the radius rod in forward gear is shown by a full line in Fig. 3, and by dash lines in Figs. 4 and 5.

14. The outside-admission valve is not applied to the present-day locomotive, which uses superheated steam, unless there is a special reason for doing so, but in some cases circumstances demand it. For example, suppose an old locomotive with outside-admission valves is to be rebuilt, and the condition of the cylinders does not warrant the expense of applying new ones. No matter what type of steam chest is applied to the old cylinders, piston valve, or flat valve, the valve and valve gear will have to be arranged for outside admission. On the low-pressure engine of a Mallet compound locomotive, the flat valve is sometimes used as the steam has lost its high degree of superheat by the time it reaches the low-

pressure valve, and the piston valve is no longer necessary. The valve gear will then be arranged accordingly.

15. Reasons for Direct Motion.—There are several reasons why it is preferable to use direct motion on all road locomotives. On switchers it is immaterial, as they work as much in back gear as in fore gear. The first reason is that, as shown in Figs. 6 and 7, the wear on the link-support bushings is very much greater with indirect motion.

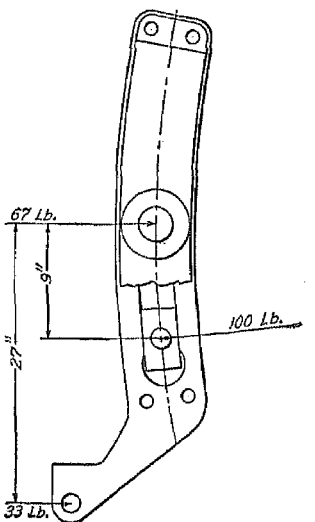

FIG. 6

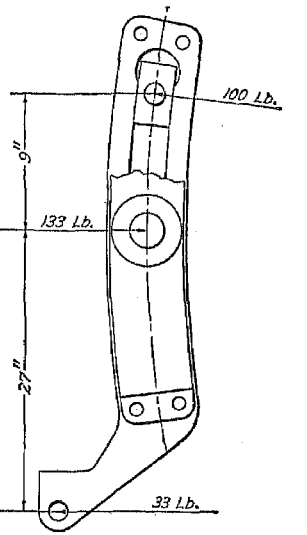

FIG. 7

In Fig. 6 is shown the condition with the link block at the bottom of the link and, assuming that it takes, say, 100 pounds to move the valve, the thrust exerted by the eccentric rod will be $\frac{100\times 9}{27}$, or about 33 pounds, and the thrust on the link-support bushings will be $100-33$, or about 67 pounds.

In Fig. 7 is shown the condition with the link block at the top of the link, and, assuming, as before, that it takes 100 pounds to move the valve, then the pull exerted by the eccentric rod will be the same, or 33 pounds. The thrust on the link-support bushings, however, will be increased to about

100+33 or 133 pounds, or double what it was with direct motion.

The next reason is that the link-block slip, and consequently the wear on the link, will be less with the radius bar in the bottom of the link, provided the radius-bar hanger is used as shown in Figs. 1 and 2, and this is the style used in the vast majority of cases. The reason is as follows: In Fig. 8, the point *a* on the link which pivots about point *c* must follow the arc *d d*, and a point *b* in the top of the link must follow the arc *e e*, and in order to eliminate the slip of the link block, the block would also have to follow these arcs exactly. This ideal condition is, of course, impossible, but it will be seen with the radius-bar hanger swinging on the arc *f f* that it will much more nearly follow the arc *d d* than it could follow arc *e e* when swinging on arc *g g*.

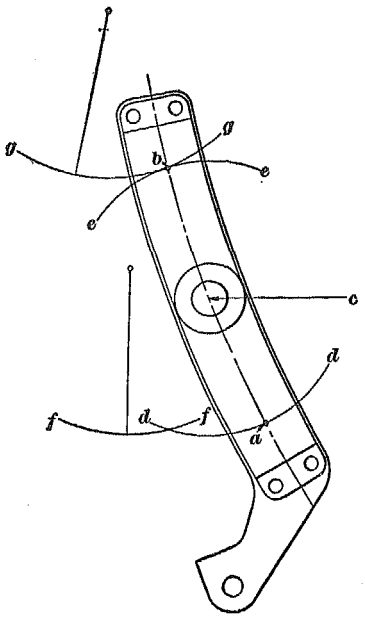

FIG. 8

16. The third, and perhaps the most important, reason is that in the event of the failure of the radius-rod hanger, reverse-shaft arm, or reverse gear, it is far better that the radius rod should drop into forward gear than into back gear, especially if the failure takes place when running at high speed. If the radius bar were to drop into back gear while running forwards at high speed, the cylinder would almost certainly be destroyed, and even worse consequences might follow.

The gear, as shown in Fig. 1, is the arrangement which is preferred by most locomotive designers, but, as already shown, the arrangement can be varied in a good many particulars.

The tendency for several years past has been to get away from the crosshead arm entirely and couple the union link directly to the wristpin in the main crosshead. This arrangement cuts down the cost of the gear slightly and also eliminates the maintenance of the bolting on the crosshead arm, which was giving some railroads considerable trouble.

GENERAL ORDER OF VALVE-SETTING OPERATIONS

17. The general order of the valve-setting operations is as follows: (1) The dead centers are located on the main driving tire. (2) The port marks are made on the valve stem. (3) The lap and lead movement is tested. (4) The eccentric crank is set. (5) The length of the eccentric rod is corrected.

CHECKING

18. Checking Port Spacing.—To facilitate the actual setting of the valves, there are several points which should be carefully looked after while the parts are being manufactured or repaired and during assembly.

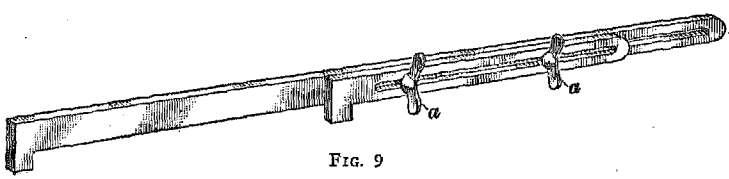

FIG. 9

The spacing of the ports in the steam chest should be checked accurately, first taking care that any carbon deposit on the edges of the ports has been removed. With piston valves, a gauge will be necessary to do this work, two pieces of plate fastened together by two short bolts with wing nuts *a*, as shown in Fig. 9, will be satisfactory.

The steam and exhaust edges of the ports should both be measured and the valve should then be measured over the steam edges and exhaust edges in order to ascertain if the steam lap, and the exhaust clearance (if any is required), are correct.

The total steam lap, or steam lap at each end of the valve, is determined by subtracting the distance between the steam edges of the steam ports from the distance between the steam edges of the valve. If the distance between the exhaust edges of the steam ports is the same as the distance between the exhaust edges of the valve, the valve is line and line. The total exhaust clearance is found by subtracting the distance between the exhaust edges of the steam ports from the distance between the exhaust edges of the valve, and the total exhaust lap, by subtracting the distance between the exhaust edges of the valve from the distance between the exhaust edges of the ports.

The foregoing refers to an outside-admission valve. With an inside-admission valve the total steam lap is found by subtracting the distance between the steam edges of the valve from the distance between the steam edges of the ports. The total exhaust clearance is found by subtracting the distance between the exhaust edges of the valve from the distance between the exhaust edges of the ports, and the total exhaust lap by subtracting the distance between the exhaust edges of the ports from the distance between the exhaust edges of the valve.

19. If the port spacing and the valves check up exactly with the arrangement drawing, the lap and clearance will be correct, but if there is an error, the proper adjustment to correct it should be made before the valves are applied. With the flat valve the port spacing and the valves are nearly always correct, but errors are often found in the port spacing for piston valves on account of the valve bushings being set in too far or not far enough, and if the error is considerable (say anything over $\frac{1}{16}$ inch), at least one valve bushing should be removed and a new one applied to correct the error. If the error is very slight, the adjustment may be made on the body casting of the valve; a slight amount may be turned off or a thin liner pegged on to one end of the casting to make the proper correction. The practice of correcting the error just mentioned by applying special valve packing rings should be

strongly condemned, for, although the valve would be quite correct when going into service, it is fairly safe to assume that standard rings will be applied and the valves thrown out of square the first time the packing rings are changed in the roundhouse.

20. Inspecting and Checking Gear Parts.—All other parts of the gear should be carefully inspected before being sent to the erecting shop, and the length between the centers of pins and offsets should be accurately checked.

To measure the distance between the centers of two holes, insert the pins and measure from center to center of the pins. If the pins have not yet been made and fitted, the distance between the centers can still be measured without much

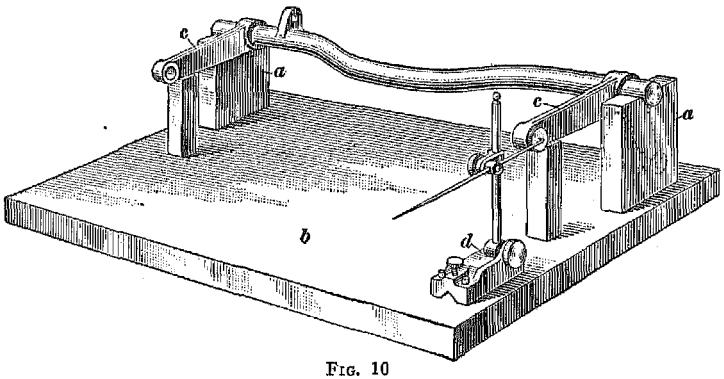

FIG. 10

trouble; for example, if the holes are of equal diameters the distance from the right-hand edge of one hole to the right-hand edge of the other will be equal to the distance between the centers. If the holes are of unequal diameters, the distance between centers will be equal to the distance between the inside edges of the holes, plus one-half the diameter of the larger hole, plus one-half the diameter of the smaller hole.

If there is a slight error in the length of the eccentric rod, it should not be corrected, because in the great majority of cases this rod has to be sent to the smith shop for lengthening or shortening when the final adjustments are made. The same applies to the radius rod in some shops, but this depends on

local practice, and this point will be dealt with later on. The reverse shaft should be set up in V-blocks *a* on the marking slab *b*, Fig. 10, or on the table of a planing machine and the arms *c*, which carry the radius-rod hangers, should be checked up with a surface gauge *d* to make sure that the pins correspond exactly in height on both sides of the engine.

21. The link should be checked both for the radius of the slot and the backset of the link foot or the amount the link foot *4*, Fig. 1, is behind the link. Most shops carry a set of gauges for checking the radii of the different links which they have in service, but if there are no gauges, they are quite easily made. The object of backsetting the link foot is to give the valve an equal travel both front and back of its central position, thereby insuring an equal opening at the front and back ports. The valve setter is not permitted to alter the backset, provided it checks exactly with the drawing. If the gear is carefully inspected and checked before it is assembled, a great deal of time and work will be saved for the valve setter.

APPLYING THE GEAR

22. The valve gear must be applied to the locomotive in accordance with the arrangement drawing, and care must be taken that all parts fall into line without forcing. For example, the fork end of the eccentric rod should lead fairly on to the link foot without requiring to be sprung in either direction. The pin should be put into its place by hand without the necessity of putting a bar into the fork and twisting it to allow the pin to enter. Always bear in mind that, if the parts have to be forced together, they will not run freely, and the pins will seize within a few days and probably result in an engine failure. The tools to be used, should any rod require a slight amount of setting or twisting, will be described further on. The valves are placed in the steam chest and the valve stems connected to their crossheads, the main rods are temporarily applied, but the side rods are left off until after the valves have been set.

In the case of a locomotive undergoing repairs, the eccentric crank is temporarily set to its old position, but in the case of a new locomotive, the first trial setting is made by means of the gauge shown in Fig. 11. To use the gauge, the diameter of the eccentric circle is obtained from the erecting card or arrangement drawing, and the point on the arm *a*, view (*a*), is set one-half of this amount from the center of the spindle *b*. The gauge is then placed on the end of the main axle *c*, view (*b*), in such a way that the spherical end of the part *b*

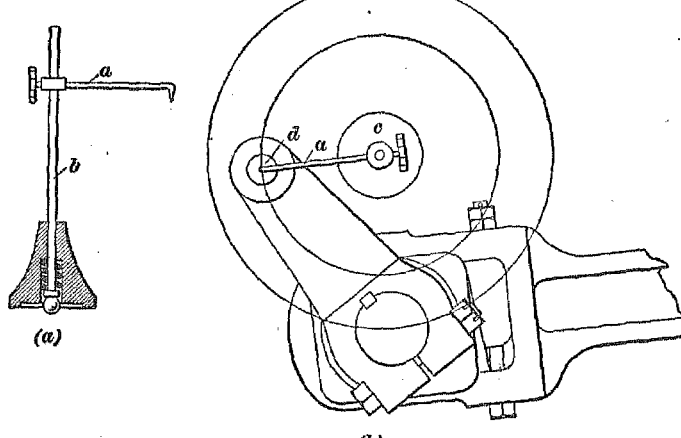

FIG. 11

enters the lathe center. The eccentric is then located so that the point of the gauge exactly coincides with the center of the eccentric pin *d*.

A bolt which is smaller in diameter than the one that will be finally applied is used during the period of setting to grip the eccentric crank on to the main crankpin. This allows the setting to be changed slightly when necessary.

DEAD CENTERS

23. Turning Driving Wheels.—In order to try over the valve events of any locomotive, it is necessary to have some means of rotating the main axle. In the early days of

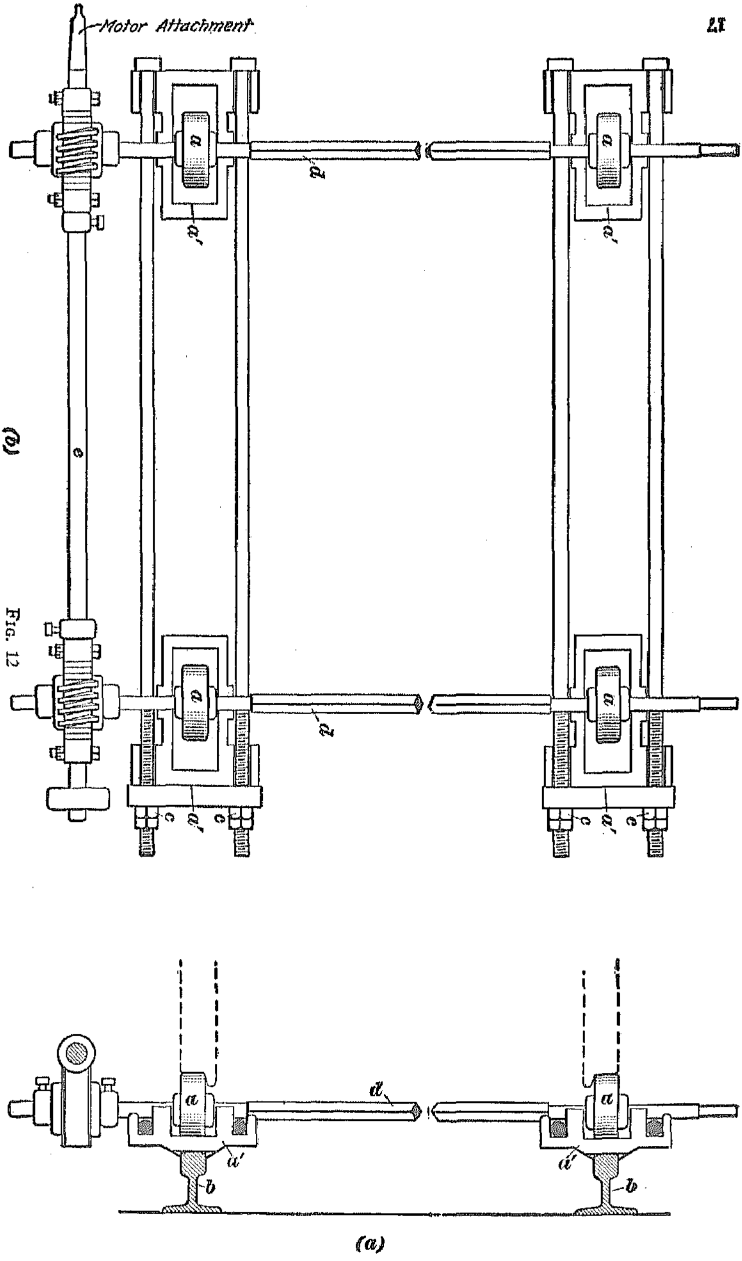

Fig. 12

railroading it was customary to do this by moving the locomotive backwards and forwards on a level piece of track by means of pinch bars. This was an expensive and tedious operation, and, with the heavy locomotives of today, it would be impossible.

The present-day practice is to raise the main wheels just clear of the rail by means of a set of rollers like those shown in Fig. 12. Nothing is to be gained by rotating any other but the main axle, and this is why the side rods are left off until after the valve setting is done. These rollers are generally operated by pneumatic or electric power, but where power is not available they are fitted with ratchets and levers.

The frames a' are placed on the rails b, Fig. 12 (a), at the front and back of the main driving wheels, and by tightening the nuts c, view (b), the rollers a are drawn closer together, and the wheels are lifted clear of the rails. The rollers and, therefore, the wheels are rotated by the shaft e, the worms of which engage the worm-gears on the shafts d. The distance from the center of the main axle to the top of the frame is then checked and, if necessary, jacks are placed under the main frames at the front and back to raise them to their correct relative position.

The reason is that the rollers have lifted the main drivers slightly, and they probably are not in the same relative position to the frame that they will be when the engine is running, and the frame should, therefore, be brought to its correct position before the work of valve setting is begun.

24. Definition of Dead Center.—A locomotive is said to be on a dead center when the center of the main axle, the main crankpin, and the wristpin in the crosshead fall in one straight line. In a locomotive with two cylinders and the cranks set at right angles to each other, there are naturally four positions in which this condition is met. Then the dead centers, taken in order through one complete revolution of the main wheels, are the right front dead center, left front dead-center, right back dead center, and left back dead center.

One of the fundamentals of good valve setting is to be perfectly accurate in marking the dead centers, because the accuracy of the setting is checked by the leads which are measured on the dead centers. Also, owing to the fact that the valve on that particular side is traveling faster than at any other point as the engine reaches the dead center, a slight error will appreciably affect the readings of the valve events.

25. Finding Dead Centers.—To find the right front dead center, turn the driving wheels forwards until the crosshead is within a short distance—say one-quarter of an inch—of the end of its stroke.

In Fig. 13 are shown the relative positions of the main axle *a*, main crankpin *b*, and wristpin *c* in this position. Now make a center-punch mark *d* on the crosshead shoe, and by means of the tram *1*, scribe a line *e* on the guide bar. Also make a center-punch mark *f* on the motion support, brake-hanger stud, or any convenient part of the locomotive which is permanently fixed, and by means of the tram *2*, scribe the line *g* on the tire of the main wheel. Scrape off any grease or dirt from around the center-punch mark *f* and chalk a ring around it, in order that it may be easily found, for this mark will be used constantly throughout the process of valve setting. Next, turn the wheels forwards until the main crankpin *b* has gone over the dead center, and continue the rotation until the tram *1* held on the center-punch mark *d*, will strike a point about $\frac{1}{8}$ inch back of the mark *e*. Then turn the wheels backwards very carefully until the point of the tram *1*, held in the center-punch mark *d*, exactly coincides with the mark *e*. The line *a b' c* shows this position of the main crank and the main rod. Should the tram *1* happen to run by the mark ever so slightly, it will be necessary to turn the wheels forwards again far enough to clear the mark *e* by about $\frac{1}{8}$ inch and then turn the wheels backwards and come up to the mark *e* from the proper direction. When the wheel is stopped with the tram *1* exactly on the line *e*, place the tram *2* in the center-punch mark *f* and scribe another line *h* on the face of the tire. Then, with a pair of hermaphrodites, scratch the line *i j* about the middle of

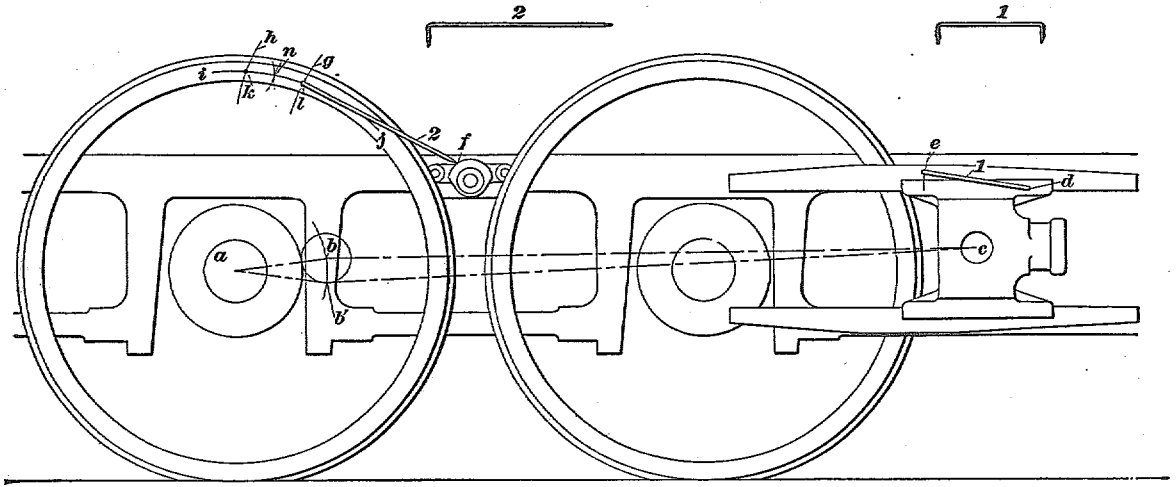

FIG. 13

the face of the tire and make light center-punch marks at *k* and *l* where it intersects the lines *h* and *g*. The line *i j* is scribed by moving one leg of the hermaphrodites along the edge of the tire while holding the point of the other leg against the side of the tire. The line *i j* is scribed so that the points *k* and *l* will be the same distance from the edge of the tire. With a pair of dividers, find the mid-point between *k* and *l* on the line *i j* at *n* and make a good center-punch mark. Then chalk a ring around it to make it easy to locate, and also chalk the letters *R F*, meaning *right front*, as this may save some confusion when taking readings.

Now, if the wheels are turned to such a position that the tram *2*, when held in the center-punch mark *f*, also exactly enters the center-punch mark *n*, then the locomotive is on the right front dead center. The reason is that the main crankpin is the same amount ahead of the dead center at *b'*, as it is back of the dead center at *b*. Hence, the pin, when half way between these points or with the tram at *n*, is on the dead center.

26. The object of turning the wheels forwards far enough for the tram *1* to pass the line *e* and then coming back on to this line from the other direction, is to neutralize the effect of lost motion in the main-rod brasses, and by working in this manner the same big-end brass and the same small-end brass bears on the main crankpin and wristpin respectively when the marks *g* and *h* are scribed on the tire.

Proceed in the same way to locate the left front, right back, and left back dead centers, marking them *LF*, *RB*, and *LB*, respectively, and taking care to neutralize the effect of lost motion in the main-rod brasses as before. The same center-punch mark *f* is used for all dead centers and the same tram *2*. However, the center-punch mark *e* will naturally have different positions for the front and back dead centers on both the right- and left-hand guide bars. It is preferable to locate all four dead-center marks on one wheel, and this wheel should be the one on whichever side of the locomotive the motive power for the rollers is situated, in order that the man

who is handling the tram *2* may be within easy speaking distance of the man who is running the rollers. That is, if the rollers are turned from the right side, tram *2* will be used on the right-hand tire for all four dead centers, but tram *1* will, of course, be used on the right-hand crosshead for the right front and right back dead centers, and on the left-hand crosshead for the left front and left back dead centers. The order in which the dead centers are taken is of no importance, neither is the direction of rotation, The wheels may be turned in either direction so long as the general principles just outlined are strictly adhered to.

With the dead centers located, there are four points in the revolution of the main wheels from which to work, because the position of the piston can be definitely located from these points. As the purpose of valve setting is to give the valve its correct movement relative to the movement of the piston, definite points are now needed from which to gauge the position of the valve. By means of port marks on the valve stem, the position of the valve can be determined at any point in the stroke of the piston.

PORT MARKS

27. Definition.—*Port marks* are marks on the valve stem which are used to determine when the steam edge of the valve is in line with the steam edge of the port, and also the amount the valve has the port opened or closed to steam. Marks that are made on the valve stem to locate the position of the valve at release and closure are called *exhaust port marks*.

28. Making the Port Marks.—To make the port marks, the wheels are turned until the crosshead is about in mid-position. Then, by means of the reverse lever, the valve is moved until it is just on the point of opening the front port to steam, that is, with the steam edge of the valve exactly in line with the steam edge of the port. In Fig. 14 (*a*) is shown an outside-admission valve, and in Fig. 15 (*a*) is an inside-admission valve in the position just described.

Next make a center-punch mark at *a*, on any convenient part of the cylinder or steam chest that is permanently fixed, and with one end of the tram *3*, in this mark, scribe a line *b* on the valve stem. Then move the valve by means of the reverse lever until it is on the point of opening the back port to steam, Figs. 14 (*b*) and 15 (*b*), and with the tram *3*, and the center-punch mark *a*, scribe a second line *c* on the valve stem. It

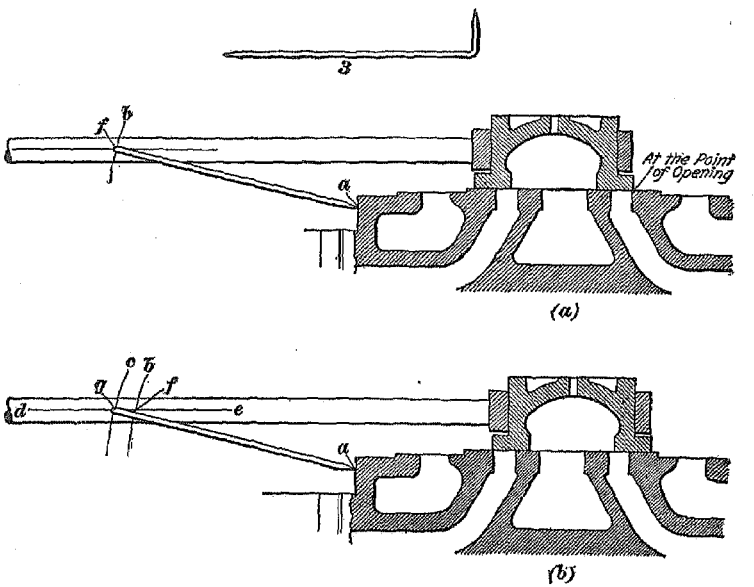

FIG. 14

will be noted that an outside-admission valve has to be moved forwards, and the inside-admission valve backwards to bring them to a point where they are on the point of opening the back port.

29. Next mark a line *d e*, Figs. 14 (*b*) and 15 (*c*), parallel with the center line of the valve stem and make two light center-punch marks *f* and *g* exactly where this line intersects the lines *b* and *c*. The mark *f* is the front port mark and the mark *g* is the back port mark. The distance between the two marks is twice that of the steam lap. By making the

port marks on the other valve stem in the same way, all the port marks necessary for ordinary valve setting are obtained. With a slide valve, the port marks have to be made before the steam-chest cover is applied, but with a piston valve the edges of the ports can be observed by removing the peep-hole plugs. If peep holes are not provided, the port marks for an

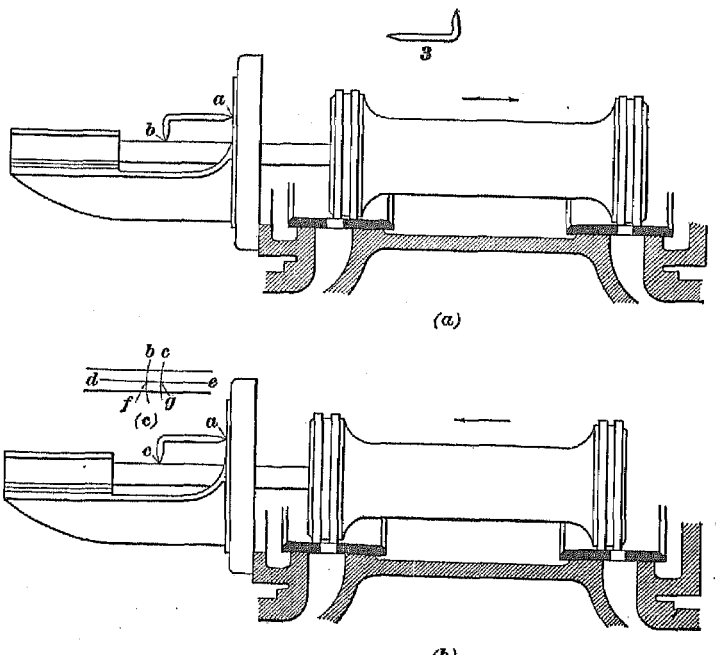

FIG. 15

inside-admission valve can be found as follows: With the valve in the steam chest, place the outside edge of the front exhaust ring in line with the outside or exhaust edge of the port if the valve is line and line on the exhaust side. If exhaust clearance is specified, place the ring the amount of the clearance from the edge of the port. The valve is now in central position, and the center port mark can be obtained by marking the valve stem with the tram. The front port mark will be the amount of the steam lap behind the center port mark, and,

the back port mark, the amount of the steam lap ahead of the center port mark. It is advisable to remove any grease or dirt from around the center-punch mark *a* and to make a small ring around it with chalk; this will make the center-punch mark easy to locate and will prevent mistakes. The position of either valve can be determined by placing the tram in the mark *a*, then scribing a light line on the valve stem, and measuring the distance from the line to a port mark.

30. Position of Port Marks With Outside- and Inside-Admission Valves.—The position of the port marks on the valve stem with an outside-admission valve is just opposite to their position with an inside-admission valve. With an outside-admission valve, Fig. 14 (*b*), the front port mark *f* is the one nearest to the steam chest and is ahead of the back port mark *g*, but with an inside-admission valve, Fig. 15 (*c*), the back port mark *g* is nearest the steam chest and is ahead of the front port mark *f*. The reason that the port marks are reversed is due to the fact that the steam edges of an outside-admission valve are on the outside of the valve, whereas with an inside-admission valve, the steam edges are on the inside of the valve.

31. Exhaust Port Marks.—In cases where a complete report of all the valve events is required, including the release and closure points, it will be necessary to make port marks to show the points where the valve is on the point of opening and closing the front port and the back port to the exhaust. If the exhaust setting is line and line, only one mark will be needed, as the exhaust edges of the valves will coincide with the exhaust edges of both the front and the back ports when the valve is in its mid-position; but if the required setting has exhaust clearance or exhaust lap, two marks will be required and the distance between them will be double the exhaust clearance or double the exhaust lap. If the exhaust port marks are necessary, they can be located as follows: Locate a center exactly half way between the two port marks and then scribe the exhaust port marks a distance on each side of this center mark, equal to the exhaust clearance or the exhaust lap.

CHECKING AND ADJUSTING

32. Checking Alinement of Reverse-Shaft Arms and Radius-Rod Hangers.—The first step in the actual setting of the valves, now that the fixed points are located on the wheels and the valve stems, is to check the alinement of the reverse-shaft arms and radius-rod hangers; for, even though these parts have been carefully checked before assembly, there may still be a slight error somewhere which will affect this part of the mechanism. For example, one link support *16*, Figs. 1 and 2, may be just a shade higher than the other, or the reverse-shaft bearings *g*, Fig. 2, may not be exactly level with each other. If any of these errors are present, they will probably be very slight; but a combination of slight errors may be serious enough to necessitate some adjustment.

33. Checking Length of Reach Rod.—To check the length of the reach rod, place the locomotive on the left front or left back dead center, it does not matter which; this brings the combination lever vertical on the right side. Then put the reverse lever in the middle notch on the quadrant and disconnect the front end of the right-hand eccentric rod from the link foot. Now take hold of the link foot and rock the link backwards and forwards. If the valve remains stationary, the link block must be exactly in the center of the link and, therefore, the reach rod is of the correct length. If the valve moves forwards as the link foot moves forwards, the link block must be below the center of the link. If the valve moves backwards as the link foot moves forwards, it necessarily follows that the link block is above the center of the link.

34. Adjusting Length of Reach Rod.—If there is any movement of the valve, adjust the length of the reach rod to bring the link block central in the link. This is easily done by taking out the pin that connects it to the reverse crank and screwing the reach-rod end on or off the required distance. When the reach rod has been connected again to the reverse-shaft crank, rock the link backwards and forwards and again

watch the valve. If it remains perfectly still, the reach rod is of correct length and will not be altered again until the work of valve setting has been completed and the proper adjustment made to allow for the expansion of the boiler. In this case it is assumed that the valves are set while the engine is cold, as is nearly always the case.

35. Checking Left-Hand Radius-Rod Hanger.—To check the left-hand radius-rod hanger, turn the wheels and place the locomotive on the right front or right back dead center; this will bring the left-hand combination lever to a vertical position. Leave the reverse lever in the center notch, disconnect the front end of the left-hand eccentric rod from the link foot, rock the link in the same way as was done to the right-hand one, and watch the valve to see if there is any perceptible movement.

If any movement is observed in the valve, it will be necessary to lengthen or shorten the radius-rod hanger on the left-hand side the amount required to bring the link block central in the link. This should be attended to before proceeding further with the setting. The radius-rod hanger is lengthened or shortened in the same manner as the radius rods, the adjustment of which will be explained further on. Having adjusted this part of the gear properly, the eccentric rods may again be connected up with the link feet. The next step is to correct the lap-and-lead movement.

CORRECTING LAP-AND-LEAD MOVEMENT

36. Movement Derived From Combination Lever. If the reverse lever is left in the center notch, the valve cannot obtain any motion from the link, because the corrections have just been made that will prevent any movement of the valves with the reverse lever in this position. Therefore, any movement of the valve must be derived entirely from the main crosshead through the combination lever. The movement that the valve derives from the combination lever is equal to twice the steam lap plus twice the lead. Thus with, say, a

$1\frac{1}{16}$-inch lap and $\frac{1}{4}$-inch lead, the valve movement obtained from the crosshead and combination lever should be twice $1\frac{1}{16}$ inches plus twice $\frac{1}{4}$ inch, or $2\frac{5}{8}$ inches. The length of the valve and the port spacing has already been checked so as to insure that the steam lap was correct before the valve was placed in the steam chest, and if the combination lever has also been carefully checked for length, the correct valve travel will be obtained from the main crosshead. The only error likely to be found is unequal leads at the front and back ports.

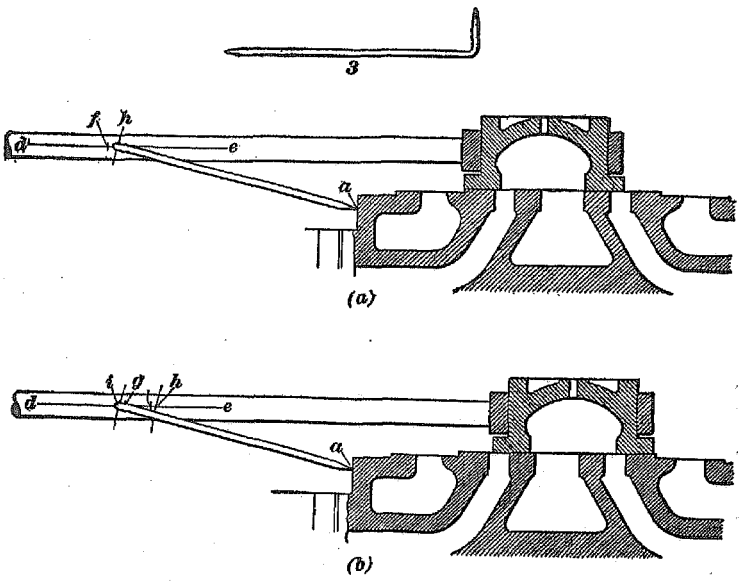

FIG. 16

The valve setter is never permitted to change the length of the combination lever; he only checks its length with the drawing. If there is anything wrong with the design, it is a matter for the engineering department to check. An error is very rarely found in this lever.

37. Finding the Lead.—With the port marks *f* and *g*, Figs. 14 (*b*), on the valve stem, the lead, or the port opening which exists with the locomotive on the dead centers, can be found for an outside-admission valve as follows: To find the

lead at the front steam port on the right side, place the locomotive on this side on the forward dead center. Then place the end of tram *3* in the center-punch mark *a*, Fig. 16 (*a*), and scribe a light line *h* on the valve stem. With a pair of spring dividers, measure from the intersection of the line *h* with the line *d e*, to the front port mark *f*. This distance is the amount the valve has the front port open to steam, or it is the lead, because the engine is on the dead center. To

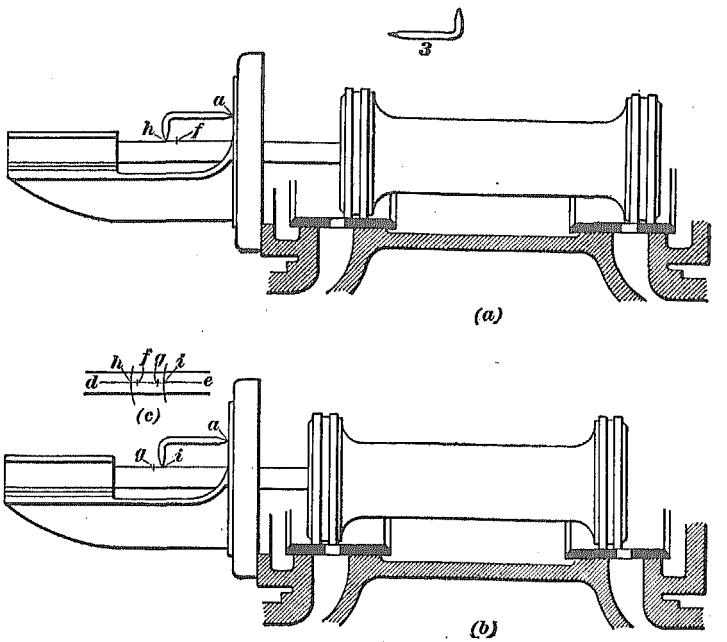

FIG. 17

find the lead at the back port on the right side, place the locomotive on the back dead center and scribe a line *i*, Fig. 16 (*b*), on the valve stem. The distance between the intersection of the line *i* with the line *e d* to the back port mark *g* is the lead at the back steam port.

The lead with an inside-admission valve, Fig. 17, is found in the same way. The line *h*, view (*a*), is scribed with the engine on the front dead center, and the line *i*, view (*b*), with the engine on the back dead center. In view (*c*) the distance

between the intersection of the line h with the line $d\ e$ to the front port mark f is the lead at the front port, and the distance between the intersection of the line i with the line $d\ e$ and the back port mark g, is the lead at the back port.

The lines h and i, with both outside- and inside-admission valves, fall outside of the port marks when the valve has lead. If the line falls between the port marks, the valve is said to be blind, or has the port closed on that particular dead center by whatever distance this line is from the port mark. The lead at the front and the back ports on the left side is found in the same way as on the right side. The order in which the leads are taken does not matter, but, to save time, first take the one that requires the least movement of the wheel to obtain, and then take the others in the order the dead centers are marked on the tire of the main driver.

38. Lead Readings Obtained.—Assume, with inside-admission valves, that the lead has been measured on all four dead centers, and that the result is as shown in Fig. 18, in which the dots on the valve stem represent the port marks, and the crosses, the lead marks. On the right-hand valve stem, there is $\frac{5}{16}$-inch lead at the front port and $\frac{3}{16}$-inch at the back port. On the left-hand valve stem, there is $\frac{9}{16}$-inch lead at the front port, and the valve is $\frac{1}{16}$-inch blind at the back port, or the back port is closed this amount. The lead specified in this case is $\frac{1}{4}$ inch, so that the valve travel derived from the main crosshead is correct, because there is a total of $\frac{1}{2}$-inch port opening on either side, which only requires to be divided equally between the front and the back ports. Thus, the right side shows $\frac{5}{16}$ inch, front, and $\frac{3}{16}$ inch, back, total $\frac{1}{2}$ inch; the left side shows $\frac{9}{16}$ inch, front, minus $\frac{1}{16}$ inch back, or a total of $\frac{1}{2}$ inch.

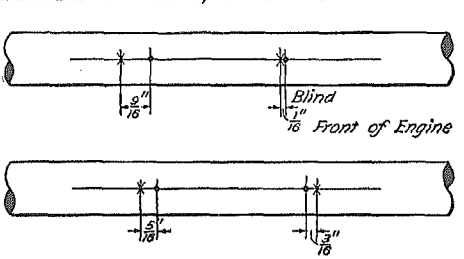

FIG. 18

39. Calculating the Correction.—The amount of correction required and the direction the valve is to be moved to correct the error when the leads are unequal, can be found from the following rule:

Rule.—*Subtract the smaller lead from the larger lead and divide by two. If the valve is blind at one port, add the amounts and divide by two. Then move the valve the amount calculated in a direction to reduce the greater error.*

If this rule is applied to the lead readings on the right side, the correction required is found as follows: $\frac{5}{16}-\frac{3}{16}=\frac{1}{8}$, and $\frac{1}{8}\div 2=\frac{1}{16}$, which is the correction required. On the left side, one port is blind, hence, according to the rule, the leads must be added. Thus, $\frac{9}{16}+\frac{1}{16}=\frac{5}{8}$, and $\frac{5}{8}\div 2=\frac{5}{16}$, the correction required.

As the valves are inside-admission, the valve on the right side has to be moved back $\frac{1}{16}$ inch to make the correction, because the greater lead is at the front port. This reduces the lead on the front dead center $\frac{1}{16}$ inch and gives a lead of $\frac{5}{16}-\frac{1}{16}=\frac{1}{4}$ inch. A movement backward of $\frac{1}{16}$ inch increases or adds to the lead on the back dead center and will give a lead of $\frac{3}{16}+\frac{1}{16}=\frac{1}{4}$ inch. Hence a correction of $\frac{1}{16}$ inch makes the leads equal at both ports.

40. The left-hand valve has to be moved back $\frac{5}{16}$ inch in order to make the leads equal. This reduces the lead at the back port $\frac{5}{16}$ inch and will leave a lead of $\frac{9}{16}-\frac{5}{16}=\frac{1}{4}$ inch on the front dead center. A backward movement of $\frac{5}{16}$ inch will also give a lead of $\frac{1}{4}$ inch on the back dead center, because the valve is blind and has to move back $\frac{1}{16}$ inch before the port begins to open.

If these same readings had been obtained with outside-admission valves, it would have been necessary to move both valves in the opposite direction, that is, ahead, because the movement would have to be in the proper direction to correct the greater errors.

41. Should one not care to calculate the correction required in the manner just described, the same result may be obtained very simply as follows: In Fig. 19 are shown portions of the

valve stems of the locomotive with the port marks f and g and the lead marks h and i. Take a pair of spring dividers and locate a point p midway between the port marks f and g on each valve stem and scratch a line as shown intersecting the line d e. Then find the point s midway between the lines h and i on the right-hand valve stem and the point s' midway between lines h and i on the left-hand valve stem. The distance from p to s, or $\frac{1}{16}$ inch, will be the correction

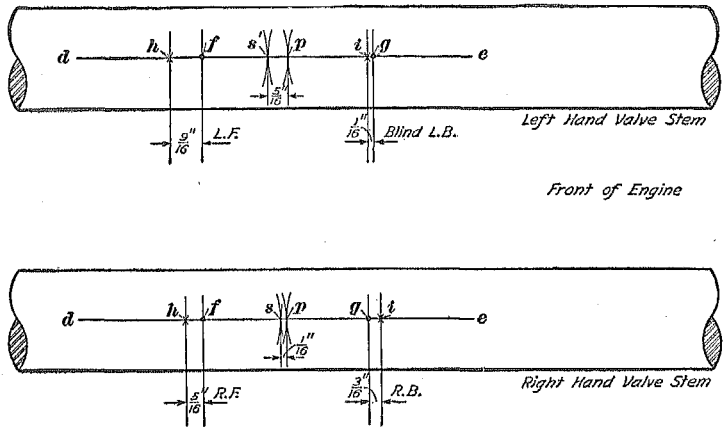

FIG. 19

required on the right-hand side, and the distance from p to s', or $\frac{5}{16}$ inch, will be the correction required on the left-hand side.

If the application of the rule in Art. **39** does not give the lead specified in the arrangement drawing, an error has been made in checking the port spacing, the valve, or the combination lever. For example, assume that the specified lead is $\frac{1}{4}$ inch, and that the lead at the front port is found to be $\frac{1}{16}$ inch, and at the back port $\frac{3}{16}$ inch. According to the rule, the correction required would be $(\frac{3}{16}-\frac{1}{16})\div 2=\frac{1}{16}$. Moving the valve forwards $\frac{1}{16}$ inch would give a lead of $\frac{1}{8}$ inch at both ports, but the required lead is $\frac{1}{4}$ inch, showing that the port spacing, the valve, or the combination lever must have been checked incorrectly.

42. Part to Be Corrected.—Having decided on the corrections to be made, the only question remaining is what part

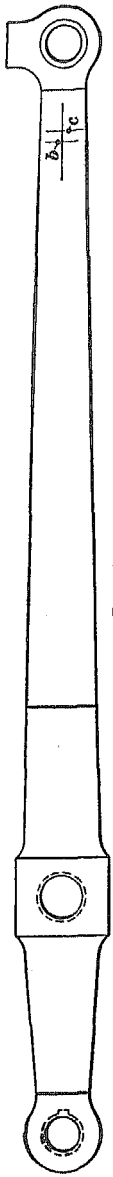

Fig. 20

of the gear should be altered to make the correction. The only two parts that can be changed to bring about the desired results are the valve stem or the radius rod.

On some railroads there are strict instructions against altering the length of the radius rod, it being maintained that the length of this part should be kept absolutely to the drawing in order that it may exactly sweep the radius of the link slot. In such a case the valve setter has to govern himself accordingly and make any changes required on the valve stem.

In order to change the length of the valve stem, it is necessary to disconnect it from the valve-stem crosshead, take out the valve and dismantle it, and then to turn off the required amount from the valve-stem collar in the case of shortening, or to place a turned washer on the valve stem in the case of lengthening. There are good reasons against this method of procedure; where the practice is allowed, most valve setters prefer to change the length of the radius rod.

If washers are used on the valve stem, there is always a chance that they may be dropped and lost in the roundhouse when the valve is dismantled to change the packing rings. If the valve should happen to be applied without the washer or with a washer of incorrect thickness, the valve would be thrown out of square.

43. It is very much less work to take down a radius rod and alter its length than it is to take out the valve and make a correction to the valve stem, and when it is considered that the radius rod is generally about 60 inches long and that it only sweeps about 9 inches above and below the center, the amount it would be off radius in a slight adjustment would be imperceptible.

If the correction is to be made on the radius rod, it should be taken down and marked by the valve setter for lengthening or shortening. If the rod is to be shortened $\frac{1}{16}$ inch, lay it on its side and scratch two lines on it near one end, as shown in Fig. 20, exactly $\frac{1}{16}$ inch apart. Then make a light center-punch marks *b* and *c* on each line, staggering them slightly, if necessary, to prevent interference with each other or confusion, and then chalk the word *shorten* on the rod and send it to the smith.

44. Changing Length of Radius Rod.—The method followed by the smith to change the length of rods is of interest. In case the valves have to be set at some terminal when there is no available smith, it will be a distinct advantage for the valve setter to know how to handle the work. Before doing any work on the rod, its alinement should be checked and the offset noted in order that it may go back on the locomotive with no other change but in the length.

A straight edge, Fig. 21, is held along the back end of the rod and the distance from its edge to the front end of the rod is carefully noted. Next take the tram *4*, Fig. 22, and inserting one end of it in the center-punch mark *b*, scribe a line on the face of the rod, and on this line make a center-punch mark *d*. Place the points of the tram in the center-punch marks *b* and *d* and make sure that they gauge exactly.

Now, considering that the marks *b* and *c* are $\frac{1}{16}$ inch apart and that the rod requires shortening $\frac{1}{16}$ inch, the part of the rod between the marks *b* and *d* will have to be shortened such an amount that when the tram *4* is held with one point in *d*, the other point will exactly enter the mark *c*. The rod is now heated to a red heat at the part which is shown shaded in Fig. 22. This has the effect of expanding its length appreciably, so, before any alteration is made in the length, the tram *4* is again held in the center-punch mark *b* and another line scratched at *e*, while the rod is hot. Now strike a couple of blows on the end of the rod to shorten it, but in such a way as not to injure or mark it, and then place one point of the tram *4* in the mark *c* and see if the other end coincides with

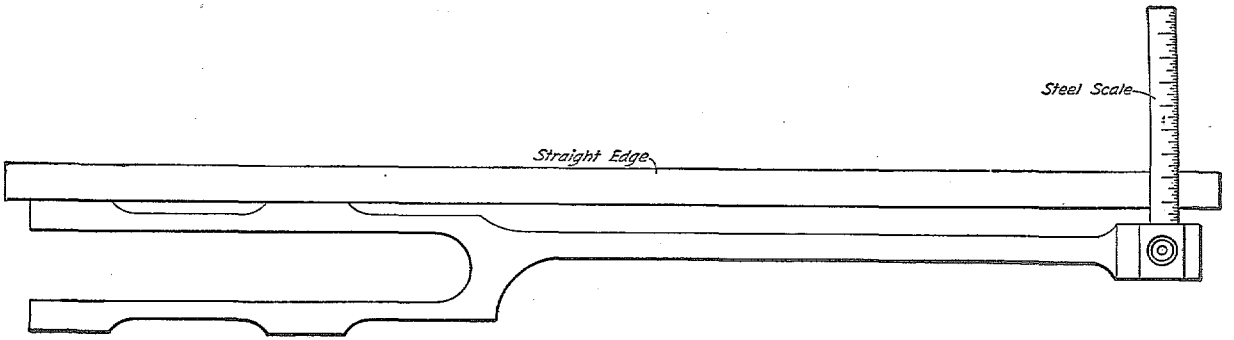

FIG. 21

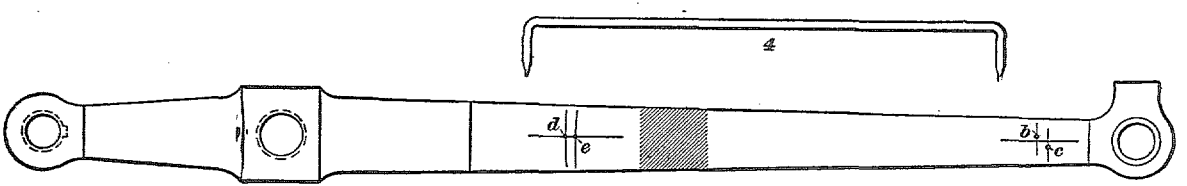

FIG. 22

the scratch *e*. If it does not, alter the length of the rod until it does, and then allow the rod to cool. A light rod such as the radius rod is generally shortened by bumping the end against a block of wood or a slab of lead lying on the floor. After the rod is cold, check the length by making sure that the tram *4* exactly enters the punch marks *d* and *c*. A smith familiar with this work will nearly always make the rod length correct at the first attempt.

45. If the rod is to be lengthened, the word *lengthen* is chalked on it, and it is checked for alinement and twist. With one end of the tram in *c*, the line *d* is scribed, and the rod is heated. With the tram in *c* the line *e* is then scribed and the rod is drawn under the hammer until the tram points enter the marks *b* and *e*. After the rod is cold, its length is checked by making sure that the tram points enter the marks *b* and *d*.

Before sending the rod back to the locomotive, the offset is checked as shown in Fig. 21 and, if necessary, corrected. The rod is also checked to make sure that it has not been twisted; this is done by laying the rod on its side and placing a straightedge on each end and sighting over them, as shown in Fig. 23.

46. After the corrections have been made to the valve stem or the radius rod, in accordance with the practice of the railroad, and the gear assembled, the locomotive is again tried on the four dead centers, with the reverse lever in the center notch, and, if the alteration has been carefully done, the readings will show a correct lead at the front and the back ports on both the right- and the left-hand sides. If there is still an error, it must, before proceeding further, be corrected in the same way as just explained.

The lap-and-lead movement is now correctly adjusted; this movement, as has already been explained, is derived from the main crosshead through the combination lever. The other source of motion is from the eccentric through the link, and this part of the gear will be adjusted next. There are only two adjustments permissible, and these are the setting of the

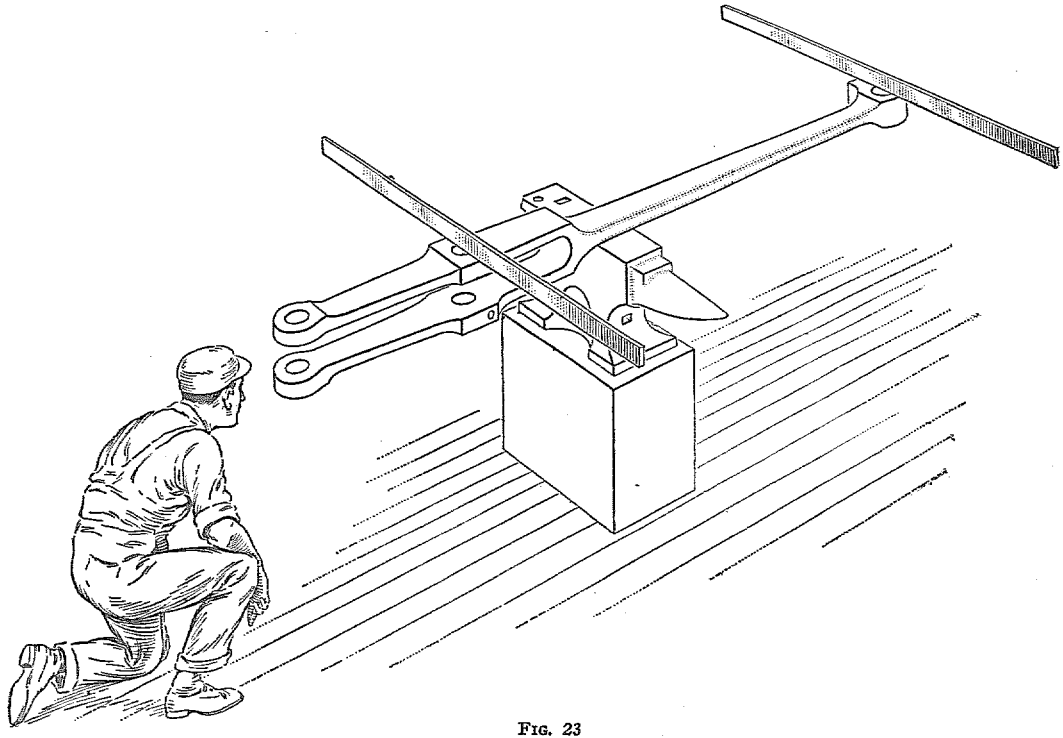

FIG. 23

eccentric crank and the length of the eccentric rod. Everything else has been checked with the drawings, and found correct.

SETTING ECCENTRIC CRANK

47. The eccentric crank is already in position and has been given a temporary setting, as before described.

To set the crank, turn the wheels to the nearest dead center, say the right front, and with tram *5*, Fig. 24, held in the center-punch mark *b* on the end of the guide bar or some other convenient fixed part of the locomotive, scratch a line on the link foot at *c*.

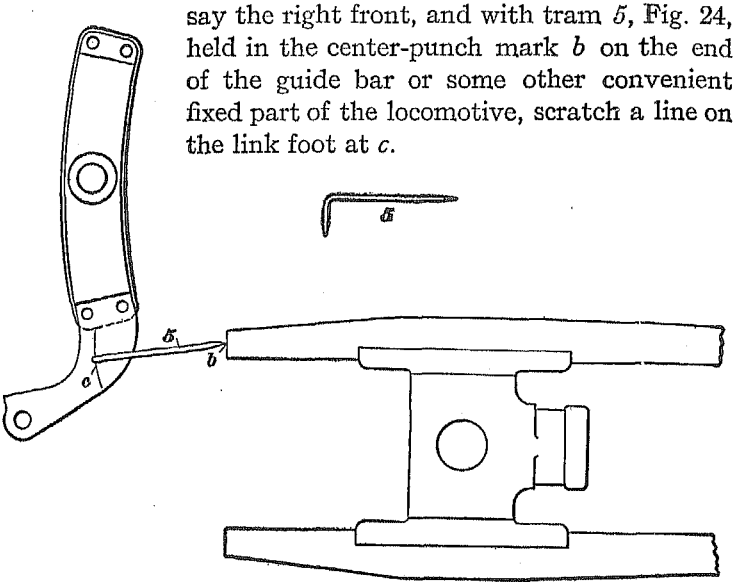

FIG. 24

Then turn the wheels to the right back dead center and, with tram *5* again held in the center-punch mark *b*, make a line on the link foot. If this line coincides with the first mark *c*, the eccentric is correctly set and it may be permanently keyed in this position. If the second line on the link foot does not coincide with the first, drive the eccentric toward or away from the axle, as the case may be, so as to bring the point of the tram *5* about midway between the two lines on the link foot, the tram being held in the center-punch mark *b* as before. Then try again on the front and the back centers, and the

tram *5* should now make only one mark on the link foot; if two marks are still observed, make the required correction and try over again before permanently keying the eccentric in position.

The left-hand eccentric is set by the same method and keyed in position. There is now only one more adjustment to make, and that is to correct the length of the eccentric rod.

CORRECTING LENGTH OF ECCENTRIC ROD

48. For the first time during the process of valve setting, the reverse lever is moved from the center notch and put in full forward gear. Then turn the main wheels on to a dead center, say the left front, and check the lead on the left-hand valve stem, as explained in Art. 37, by means of the tram *3*, Fig. 17, and dividers. If the lead shown is $\frac{1}{4}$ inch, or whatever lead is obtained when squaring the lap-and-lead movement, the eccentric rod is of the correct length. If the lead has been changed, it is evident that the eccentric rod is not of the proper length, for the link should have no influence whatever on the position of the valve when that side of the engine is on either front or back dead center, no matter what the position of the reverse lever may be. Then follow the dead centers for one revolution and note the amount of lead in all four positions. Suppose that the readings are as shown in Fig. 25, or left front, $\frac{5}{16}$ inch; left back, $\frac{3}{16}$ inch; right front, $\frac{1}{8}$ inch; and right back, $\frac{3}{8}$ inch.

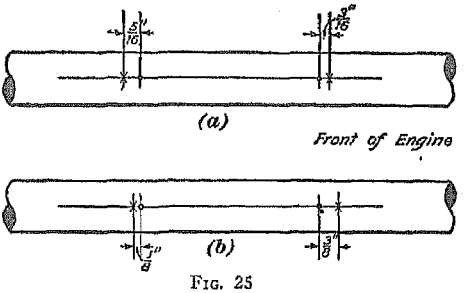

FIG. 25

The corrections required can be calculated from the rule given in Art. **39**. Thus, $\frac{3}{8}-\frac{1}{8}=\frac{1}{4}\div 2=\frac{1}{8}$ inch. This is the amount the right-hand valve is displaced from the correct position. The left-hand valve is displaced $\frac{5}{16}-\frac{3}{16}=\frac{1}{8}\div 2=\frac{1}{16}$ inch from its correct position. These displacements are

due entirely to the eccentric rods, because all other parts of the gear have been tested and found correct.

The right-hand eccentric rod will have to be lengthened or shortened such an amount that the front port will be opened $\frac{1}{8}$ inch wider, and the left-hand rod lengthened or shortened to open the back port $\frac{1}{16}$ inch wider. Whether the rods have to be lengthened or shortened will depend on whether the valves are inside- or outside-admission, and whether the gear is direct or indirect.

49. Suppose that the valves are inside-admission and that the gear is direct. An inside-admission valve has to move forwards to increase the opening at the front port, and, with direct motion, the link foot has to move forwards as the valve moves forwards. Therefore, the right-hand eccentric rod has to be lengthened such an amount as to move the valve forwards $\frac{1}{8}$ inch. This will add $\frac{1}{8}$ inch to the opening at the front port and subtract an equal amount from the opening at the back port, and thereby give a lead of $\frac{1}{4}$ inch at both ports. Reasoning in the same way, the left-hand eccentric rod will have to be shortened sufficiently to move the valve back $\frac{1}{16}$ inch. This will reduce the lead $\frac{1}{16}$ inch at the front port and will leave a lead of $\frac{1}{4}$ inch, and will increase the lead at the back port $\frac{1}{16}$ inch and make the lead $\frac{1}{4}$ inch. The alteration required in the length of the rod is usually about three times the amount the valve is to be moved, but it is not safe to make an arbitrary rule, as there is nothing standard about the radius of the link-foot swing or the travel of the link block in the link.

The most accurate way of measuring the exact alteration required is to mark the end of the eccentric rod with a tram in the following manner: Place the locomotive on, say, the right front dead center, and with the tram *6*, Fig. 26, in the same center-punch mark *b* as was used to mark the link foot when setting the eccentric, scratch a line *c* near the front end of the eccentric rod. Now rotate the main wheels and check with the valve-stem tram until the valve has moved forwards $\frac{1}{8}$ inch. This, in addition to the port opening that already

exists on the dead center, or $\frac{1}{8}$ inch, will give the correct port opening, $\frac{1}{4}$ inch, on the center. When the valve-stem tram shows exactly the correct port opening, or $\frac{1}{4}$ inch, again, take tram *6*, and, holding it in the center-punch mark *b*, scratch another line on the eccentric rod at *d*. The distance between lines *c* and *d* will be the amount by which the eccentric rod is to be lengthened.

Take down the rod and make light center-punch marks exactly on the lines *c* and *d*, chalk the word *lengthen* on it and

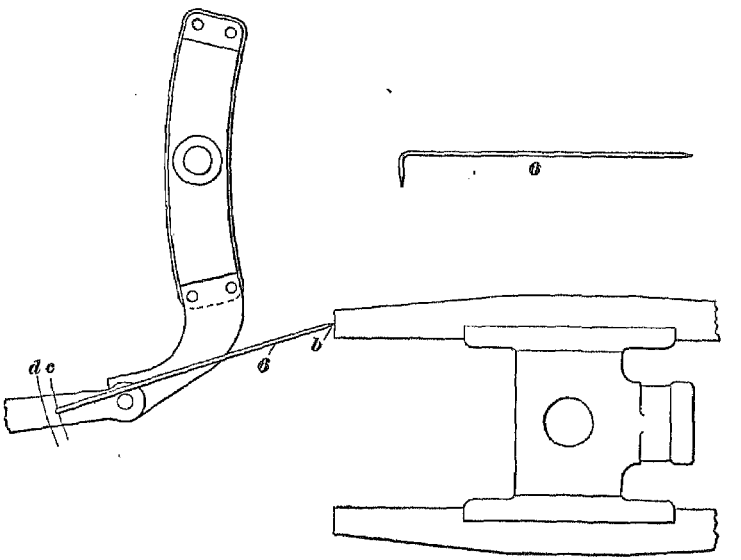

FIG. 26

send it to the smith. Next turn the wheels to the left front dead center and mark in the same way the amount the left-hand rod has to be shortened and send this also to the smith for alteration. The smith will, of course, use the same method as described before, checking carefully for offset and twist before the rods are returned to the locomotive.

50. When the eccentric rods have again been applied, place the engine on any dead center, say, the left front, and, holding the valve-stem tram on the left-hand valve stem,

have the reverse lever thrown into full back gear and forward again into full fore gear. The valve should remain absolutely stationary through the entire sweep of the lever, and should show a port opening equal to the required lead.

Place the engine on a right-hand dead center and try the right-hand valve in the same way. If the gear successfully answers this test on all four dead centers, it is as square as any valve setter can make it. The stop pins can now be placed in the quadrant to limit the travel of the reverse lever.

LOCATING STOPS ON REVERSE-LEVER QUADRANT

51. To locate the stops on the reverse-lever quadrant, place the lever in forward gear and, by means of the valve-stem tram, measure the full travel of the valve. This will be the distance from the mark on the valve stem with the valve at the end of its movement in one direction to the mark on the stem with the valve at the end of its movement in the other direction. The manner in which the extreme movement of the valve in any one direction is found is explained in Art. **57.**

If the travel is found to be less than specified, drop the lever a notch and try again. When the correct notch is located, place the stop-pin in such a way that this is the extreme forward notch that the latch can enter. If the travel is a little longer than called for, it will be satisfactory, but do not make it any shorter, or the point of maximum cut-off will occur too early in the stroke. Locate the stop-pin for back gear in the same way and the operation of valve setting will be entirely completed.

SUMMARY

52. Preliminary Operations.—The sequence of preliminary operations of setting the valves with the Walschaert valve gear is as follows:

1. Ascertain the setting that is required. By this is meant the maximum valve travel, the amount of steam lap, the lead, and exhaust clearance, or exhaust lap, as the case may be.

2. Check up all parts of the gear with the drawings; also the port spacing and the valves.

3. Carefully assemble the gear and apply the main rods and crossheads.

4. Place the rollers under the main wheels and adjust the height of the top of the frame above the center line of the axle, by means of jacks, if necessary.

53. Setting the Valves.—The preliminary of the valve-setting operations is as follows:

1. Locate the dead centers.
2. Make the port marks.
3. Check the reverse-shaft and radius-rod hangers.
4. Correct the lap-and-lead movement.
5. Set the eccentric cranks.
6. Correct the length of the eccentric rods.
7. Locate the stops on the reverse-lever quadrant.

This is not a lengthy process, as many of the operations overlap, and there is rarely any delay between them. For example, suppose that the lap-and-lead movement has been tried and the radius rods or valve stems have been taken away for alterations. The eccentrics can be set while waiting for the radius rods or valve stems to be returned.

VALVE-MOTION REPORT

54. It is customary after the valves have been set to make a report of the valve events. On a repair job, the report simply gives enough information to show that the valves have been set correctly. In the case of the first locomotive of a new design, a complete report of all valve events in several positions of the reverse lever is generally required by the designer in order that he may be satisfied that the gear will deliver the results for which it was designed.

The usual form of valve-motion report is given in Table I, and to fill out a report of this kind requires the measurement of preadmission, lead, port opening, cut-off, release, and closure.

55. Preadmission.—To measure preadmission in full gear, place the reverse lever in full forward gear and turn the main wheels toward, say, the right front dead center. Hold the valve-stem tram on the right-hand valve stem and note when the front steam port is about to open, which occurs when the point of the tram exactly enters the front port mark. Stop the wheels when the valve is exactly in this position, and then measure on the guide bar how far the main crosshead is from the end of the stroke. This distance will be the preadmission to be entered in the right side, front, full gear, forward-motion space of Table I. In full forward gear or full back gear this distance is often hardly perceptible. In Table I it is assumed to be $\frac{1}{64}$ inch.

56. Lead.—To measure the lead, rotate the wheels forwards to the right front dead center, and stop. If it should happen that the main wheel runs by the center, its rotation must be reversed far enough to take up all the lost motion; then approach the dead center again from the proper direction. When the wheels have been stopped on the dead center, measure the right front-port opening by means of the valve-stem tram and a pair of dividers. The width of the port opening will be the lead to be entered in the right-side, front, full-gear, forward-motion space in Table I. It will be supposed to be $\frac{1}{4}$ inch.

57. Port Opening.—To measure the port opening, continue the rotation of the main wheels forwards, hold the valve-stem tram on the valve stem and note the travel of the valve. When the valve has stopped at its extreme travel, scratch a line on the valve stem, revolve the wheels farther ahead to make sure that the next movement of the valve is in the opposite direction. If it is, the line just marked on the valve stem indicates the extreme port opening. Measure the distance from this line to the port mark and enter the result as the port opening on the right-side, front, full-gear, forward-motion space in Table I. Let it be supposed that this distance is 2 inches. In full gear this will not be the actual port opening, as the dimension entered is greater

TABLE I

VALVE-MOTION REPORT

Engine No. 490

Motion		Valves		Admission		Cylinders		Steam Lap Inches	Exhaust Lap	Exhaust Cl. Inches	% Cut-Off in Full Gear	
Steph.	Walsc.	P.	Sl.	Int.	Ext.	Dia. In.	Str. In.	$1\frac{1}{16}$	—	$\frac{1}{4}$	Forward Motion	Back Motion
—	V	V	—	V	—	24	28				83	82

Valve Events		Forward Motion						Backward Motion					
		Cut-Off Position Right Side			Cut-Off Position Left Side			Cut-Off Position Right Side			Cut-Off Position Left Side		
		Full Gear In.	50% In.	25% In.	Full Gear In.	50% In.	25% In.	Full Gear In.	50%	25%	Full Gear In.	50%	25%
Preadmission	Front	$\frac{1}{64}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{64}$	$\frac{3}{8}$	$\frac{13}{16}$	$\frac{1}{64}$			$\frac{1}{64}$		
	Back	$\frac{1}{64}$	$\frac{7}{16}$	$\frac{13}{16}$	$\frac{1}{64}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{1}{64}$			$\frac{1}{64}$		
Lead	Front	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$			$\frac{1}{4}$		
	Back	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$			$\frac{1}{4}$		
Port Opening	Front	2	$\frac{5}{8}$	$\frac{5}{16}$	$1\frac{5}{16}$	$\frac{9}{16}$	$\frac{5}{16}$	$1\frac{7}{8}$			$1\frac{7}{8}$		
	Back	$2\frac{1}{4}$	$1\frac{1}{16}$	$\frac{11}{32}$	$2\frac{1}{16}$	$\frac{5}{8}$	$\frac{11}{32}$	2			2		
Cut-Off	Front	$23\frac{3}{4}$	$13\frac{3}{4}$	$6\frac{1}{2}$	$23\frac{1}{2}$	$13\frac{1}{2}$	$6\frac{3}{8}$	$23\frac{1}{2}$			$23\frac{3}{8}$		
	Back	23	$14\frac{3}{8}$	7	$22\frac{3}{4}$	$14\frac{1}{8}$	7	$22\frac{7}{8}$			$22\frac{5}{8}$		
Release	Front	$26\frac{3}{8}$	22	$18\frac{1}{2}$	$26\frac{1}{4}$	$21\frac{3}{4}$	$18\frac{3}{8}$	$26\frac{1}{4}$			$26\frac{1}{8}$		
	Back	$26\frac{1}{8}$	$21\frac{3}{4}$	$18\frac{3}{8}$	26	$21\frac{1}{2}$	$18\frac{1}{4}$	$25\frac{7}{8}$			$25\frac{7}{8}$		
Closure	Front	$\frac{15}{16}$	$4\frac{3}{4}$	$9\frac{1}{2}$	1	$4\frac{7}{8}$	$9\frac{1}{4}$	1			$\frac{15}{16}$		
	Back	$\frac{7}{8}$	$4\frac{1}{2}$	$9\frac{1}{2}$	$\frac{15}{16}$	$4\frac{5}{8}$	$9\frac{1}{4}$	$\frac{15}{16}$			$\frac{7}{8}$		

NOTE.—Passenger engines to be tried over in full gear, 50 per cent. and 25 per cent. cut-off in fore gear and full gear in reverse. Freight engines to be tried over in full gear and 50 per cent. cut-off in fore gear and full gear in reverse.

than the full width of the port, but this is the figure required on the form.

58. **Cut-Off.**—The cut-off is measured as follows: Rotate the wheels forwards and hold the valve-stem tram on the valve stem and watch the movement of the stem as the valve closes the front port to steam. When the front port mark comes exactly opposite the point of the tram, stop the wheels and make sure that the point of the tram enters the port mark. Then measure on the guide bar the distance the main crosshead has moved from the right front dead center, and this will be the cut-off to be entered in the right-side, front, full-gear, forward-motion space in Table I. It will be assumed that this distance is $23\frac{3}{4}$ inches.

59. **Release.**—To measure the release, rotate the wheels forwards and at the same time hold the valve stem tram on the valve stem and watch for the point where the valve is just about to open the front port to the exhaust.

If the exhaust setting is line and line, that is, with no exhaust clearance or exhaust lap, the opening to the exhaust occurs when the valve is exactly in mid-position; but if exhaust clearance is called for in the setting, the valve opens the port before it reaches the central position, and there will be two port marks for the exhaust edges of the valve, the distance between them being double the amount of the exhaust clearance. Stop the wheels when the tram exactly enters the exhaust port mark and measure on the guide bar the distance the main crosshead has moved from the right front dead center. This distance will be the release to be entered in the right-side, front, full-gear, forward-motion space on the form. It will be supposed that this distance is $26\frac{3}{8}$ inches.

60. **Closure.**—If the exhaust setting is line and line, which means that the exhaust edges of the packing rings on the valve in the case of a piston valve, or the inside edges of the valve in the case of a flat valve, exactly coincide with the exhaust edges of the port when the valve is in the central position, the back port will close to exhaust at exactly the

same instant that the front port commences to open to exhaust. In such a case, therefore, the closure and the release points will be identical, but the dimensions to be recorded on the form will be the measurement from the *end of the stroke*, and not from the *beginning of the stroke*, as in the case of the release.

If the valve has exhaust clearance, however, its movement has to be continued a distance equal to twice the exhaust clearance before the back port closes to exhaust. Therefore, continue to rotate the wheels forwards, hold the valve-stem tram on the valve stem and watch for the point where the back port closes to exhaust. When the point of the tram exactly enters the port mark, stop the wheels and then measure on the guide the distance the main crosshead has to travel before it reaches the end of the stroke, or the right back dead center. This measurement, assumed to be $\frac{7}{8}$ inch, will be the closure to be entered in the right-side, back, full-gear, forward-motion space in Table I.

61. Readings for Forward Stroke.—The preadmission lead, port opening, cut-off, release, and closure have now been taken for the backward stroke of the right piston and the wheels are turned in the same direction and the same information tabulated for the forward stroke. Take the measurements in the same order as before, preadmission, lead, port opening, cut-off, release, and closure, and enter them all in the spaces for right-side, back, full gear, forward motion except the closure, which will, of course, be entered in the right-side, front, full-gear, forward-motion space. On the forward stroke, preadmission, cut-off, and release are measured from the position the crosshead assumes on the back dead center, and the dimension for closure will be the distance the crosshead has to travel to reach the front dead center.

The readings having been taken for the right side of the engine the readings on the left side are obtained in the same way. The reverse lever is left in full forward gear and the wheels turned in the forward direction. This completes the information on all the valve events in full forward gear.

Now place the reverse lever in full back gear, rotating the driving wheels in the backward direction and tabulate the same information in the proper spaces provided on the form.

The next step is to take the readings with the shortened cut-offs, but the procedure is exactly the same and the wheels will always be rotated in the forward direction for forward gear and in the backward direction for back gear.

62. Finding Notch for Required Cut-Off.—The only point that is apt to cause any difficulty is the placing of the reverse lever in the proper notch to give the required cut-off. Suppose that the locomotive has a 28-inch stroke and forward-gear readings are required with a 25 per cent. cut-off. First rotate the wheels until one crosshead is 25 per cent. of 28 inches, or 7 inches, from its extreme travel. Suppose that the right-hand crosshead has been stopped 7 inches from its extreme forward position with the crankpin below the axle. Move the reverse lever until the tram shows that the valve is just closing the front port to steam and drop the reverse-lever latch into the nearest notch. Now rotate the wheels backwards far enough to take up all the lost motion and then start to rotate them forwards, at the same time hold the valve-stem tram on the valve stem and watch the closing of the front port to steam. Stop the wheels when the tram exactly enters the port mark and then check the position of the crosshead; if it is within one-half an inch either way of the 7-inch mark, which was measured from the end of the stroke, the lever is in the correct position to give the required readings. If the cut-off is too early in the stroke, drop the lever a notch and try it again. If it is too late in the stroke, pull the lever up a notch and make sure that the cut-off is approximately correct before taking the readings.

ADJUSTING REACH ROD FOR EXPANSION OF BOILER

63. After the complete report has been made and approved by the proper authority, there is nothing left to be done except to make the required adjustment to the reach rod to allow for the expansion of the boiler. It is impossible to lay down a

hard-and-fast rule for the amount of adjustment required, as this will vary with the length of the boiler and the distance of the quadrant from the reach-rod connection to the reverse lever. On the average locomotive the adjustment will be from $\frac{1}{2}$ inch to $\frac{5}{8}$ inch, but if the locomotive is equipped with a power-reverse gear set well ahead of the cab, $\frac{3}{8}$ inch will usually be quite enough to lengthen the reach rod.

The best method of procedure for a valve setter who has much of this work to do, is to try the length of the reach rod after the locomotive has a full head of steam, in the same way as explained in Art. 33 for commencing to set the valves. All that is necessary to do is to disconnect the front end of one eccentric rod and place the lever in such a position that no movement of the valve is obtained when the link is rocked backwards and forwards. Then the adjustment of the reach rod is just what will be required to allow the reverse-lever latch to fall into the center notch of the quadrant. The valve setter should then note the amount the reach rod has to be lengthened, and keep his notes for future reference. The adjustment will be the same for all engines of the same class, and if the work is handled in a systematic way, it will be necessary to try only one engine of each class and the same adjustment will thereafter be made for all similar engines without wasting any time in testing the length of the reach rod. This is the last adjustment to be made, and the valve gear is now ready for service.

ALTERNATIVE METHOD OF SETTING

64. There is nothing to be gained by confining a valve setter to one rigid method of procedure, and as long as his methods are correct, do not unnecessarily delay the work, and give uniformly accurate results, it is advisable to give him a certain amount of latitude. An alternative method of setting the Walschaert gear, which has a good deal to commend it, will now be described.

65. Preliminary Work.—Assume that the required setting has been ascertained, that the gear has been carefully

checked and assembled, and that the rollers have been placed under the main driving wheels. Then find the dead centers and locate the port marks as before, and also check the reverse-shaft and radius-rod hangers.

66. Blocking Links.—The operations will now vary from the preceding ones, but the principles underlying them will be precisely the same. The next step is to disconnect the front ends of both eccentric rods and block both links in the position that they must assume when the main crank on the same side of the engine is on a dead center; that is, after the links are blocked the reverse lever may be moved backwards and forwards from full forward-gear to full back-gear without moving either valve.

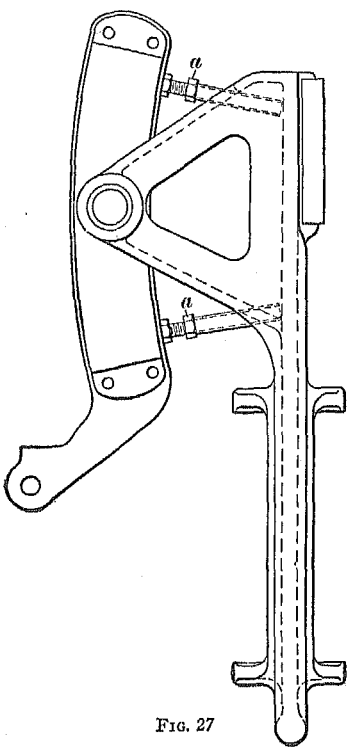

FIG. 27

The most convenient means of blocking the link are a couple of pieces of iron pipe and a bolt and nut, as shown in Fig. 27, as the link can be easily adjusted to the desired position by slackening one of the nuts *a* and tightening the other.

When both links have been blocked in this way, have the reverse lever thrown forwards and backwards, and at the same time hold the valve-stem tram on the valve stem in order to detect the slightest movement. Continue to adjust the position of the links until both valves remain absolutely stationary, no matter how far the reverse lever is moved. The links are to remain fixed in this position until all the necessary adjustments to the gear are made.

67. **To Correct Lap-and-Lead Movement.**—The lap-and-lead movement is corrected in exactly the same way as in the method previously described. Place the reverse lever in mid-gear and try the lead on all four dead centers, leaving the eccentric rods disconnected. Note the alterations required to the valve stem or radius rod to equalize the lead, and take the parts down for alteration if necessary.

68. **To Set the Eccentric Crank.**—To set the eccentric crank, turn the wheels to the nearest dead center, say the right front, and then raise the front end of the right-hand eccentric rod so that the fork end is approximately in its correct position on the link foot. Do not attempt to put the pin into the hole, but hold the rod end in place and scratch a line *a* around the end of the fork on the outside of the link foot, as shown in Fig. 28. Then come on to the left front dead center and make a similar mark on the left-hand link foot. Follow around to the right back dead center and again raise the right-hand rod and scratch a line on the link foot. If this line coincides with the line made when the engine was on the right front dead center, then the right-hand eccentric crank is correctly set. If two lines are shown on the link foot, drive the eccentric crank out or in, as the case may be, until a line scratched around the front of the eccentric-rod fork end comes exactly midway between the other two lines. Then continue the turning of the wheels to the left back dead center, again scratch a line on the left-hand link foot around the fork end of the rod and adjust the eccentric crank, if it is found necessary to do so. If adjustments are made in the setting of the eccentric cranks, try them over a second time to make perfectly sure that they are correct before keying them. Should there not be room on the link foot to scratch the

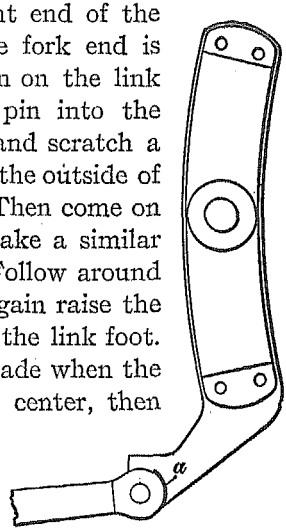

FIG. 28

FIG. 29

lines as described, the tram 7, shown in Fig. 29, can be used. A center-punch mark is made at a convenient point on the link foot and the lines are marked on the eccentric rod.

69. **To Correct the Length of the Eccentric Rod.** With the links fixed in their present position and the eccentric cranks correctly set, the pin should enter exactly at the connection of the front end of the eccentric rod to the link foot, when that side of the engine is on either the front or the back dead center. Rotate the driving wheels and stop correctly on, say, the right front dead center. Then lift the fork end of the right-hand eccentric rod up to the link foot, and if the pin can be placed in position by hand without forcing, the eccentric rod is of the correct length. If the pin will not enter, the rod will have to be lengthened or shortened by such an amount as will allow the pin to enter freely. Try the other side of the engine in the same way, and, if necessary, take down the rods, mark them for alteration and send them to the smith. If the rods have to be altered, leave the links blocked in position until the alterations are made, so that the length of the rods may be checked again before they are finally applied.

70. This is perhaps the quickest method of obtaining an accurate setting with the Walschaert valve gear, and should be especially useful for a roundhouse setting, when the locomotive can only be held out of service for a short time. In order to make the different operations clear, they have been described separately, but in practice the different adjustments can be tested simultaneously. For example, when checking the lap-and-lead movement, the locomotive is stopped on each of the four dead centers to take the lead. At this time the front end of the eccentric rods can be raised to the link feet and marked for each dead center, and the eccentric cranks set. Then the length of the eccentric rods can be checked and all parts requiring alteration taken down and marked for the smith. After all adjustments are made, the gear is assembled, the link blocking is taken out, and whatever readings are required may be taken and reported.

SETTING THE VALVES WITH BAKER VALVE GEAR

FIRST METHOD

71. Names of the Parts.—The Baker valve gear, Fig. 30 is shown applied to a locomotive with inside-admission valves and Fig. 31 is a sectional view of the gear. The names of the parts are as follows: *1*, the eccentric crank; *3*, the eccentric rod; *4*, the combination lever; *10* the bell crank; *16*, the radius rod; *19*, the reverse yoke; *22*, the valve stem; *23*, the valve-stem crosshead; *24*, the valve rod; *27*, the union link; *28*, the gear frame; *30*, the gear reach rod; *31*, the reach rod; *37*, the reverse-shaft arm; *38*, the gear connecting-rod.

72. Similarity Between the Baker and the Walschaert Gears.—The Baker valve gear closely resembles the Walschaert gear in many particulars. In both gears the valve derives its motion from two distinct sources. In the Walschaert gear these sources of motion are: (*a*) the main crosshead through the combination lever; and (*b*) the eccentric crank through the link. In the Baker gear the sources of motion are: (*a*) the main crosshead through the combination lever *4*; and (*b*) the eccentric crank *1* through the eccentric rod *3*, the gear connecting-rod *38* and the bell crank *10*.

Although the mechanical details of the two gears differ considerably, the actual movement of the valve derived from these two sources is exactly the same, and on this account the same general principles are followed in setting the valves with the Baker gear as with the Walschaert gear.

73. Preliminary Operations.—First ascertain the setting which is specified for the locomotive under consideration, that is to say, the maximum valve travel, the steam lap, the lead, and the exhaust clearance, or the exhaust lap. The port spacing and the valves should be carefully checked with the drawings, and any corrections found necessary should be made at once, as explained in Arts. 18 and 19, before the rollers are set under the driving wheels. All other parts of

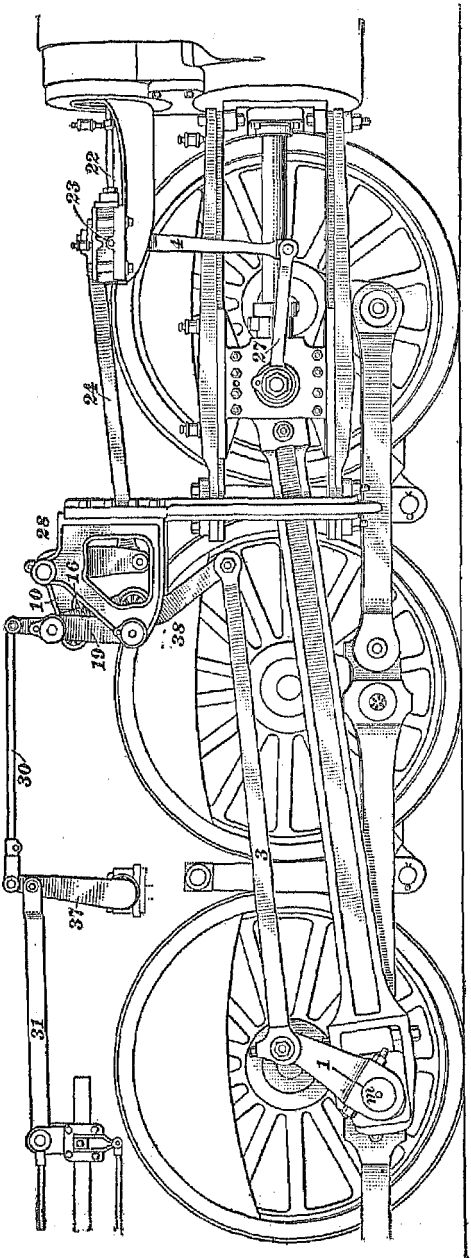

FIG. 30

the gear should be carefully inspected before being sent to the erecting shop; the length between the centers of pins or trunnions and all offsets should be accurately checked. A slight error in the length of an eccentric rod or valve rod should not be corrected before erection, as these rods generally have to be sent to the smith shop for lengthening or shortening when the final adjustments are made.

74. Application of Gear. The valves and valve gear must be applied to the locomotive in accordance with the arrangement drawing, and care should be taken that all parts fall into line without forcing. For example, the fork end of the

eccentric rod should lead fairly on to the gear connecting-rod without having to be sprung in either direction. The pin should be put into its place by hand without the necessity of putting a bar into the fork and twisting it to allow the pin to enter. Always remember that if the parts have to be forced together, the pins will soon seize and probably result in an engine failure.

The rollers, Fig. 12, can now be set under the main wheels and the main rods temporarily applied. The distance from the center line of the axles to the top of the frame is checked to make sure that it corresponds with the arrangement drawing.

75. Dead Centers.—The next step is to locate the dead centers, which are found as explained in Art. 25.

76. Port Marks.—Next make the port marks as explained in Arts. 28 and 29.

77. Squaring the Reverse Yokes.—Up to this point, the work on the Baker and Walschaert valve gears has been identical. It is now necessary to adjust the reach rods and thereby square up the reverse yokes, provided any adjustment is necessary. To square the reverse yokes, place the reverse lever in mid-position in the quadrant. The reverse yokes on both sides of the locomotive should now occupy their proper positions. To determine whether the reverse yoke on the right side is in the proper position, tram the distance between the center of the bell-crank pin to the center of the bolt that suspends the outside radius bar to the reverse yoke. This distance for inside admission valves and standard gear should be $12\frac{7}{8}$ inches; for outside admission valves, $13\frac{3}{16}$ inches; for long travel gears, $16\frac{3}{16}$ inches; and for long lap or limited cut-off gears, $16\frac{9}{16}$ inches. Check the left-hand side for the same distance. If both reverse yokes require adjustment in the same direction, make the change on the main reach rod; but, if only one reverse yoke is in the proper position, lengthen or shorten the gear reach rod on this side until the center of the bolt that suspends the outside radius bar in the reverse yoke comes the specified distance from the center of the bell-crank pin. The amount the

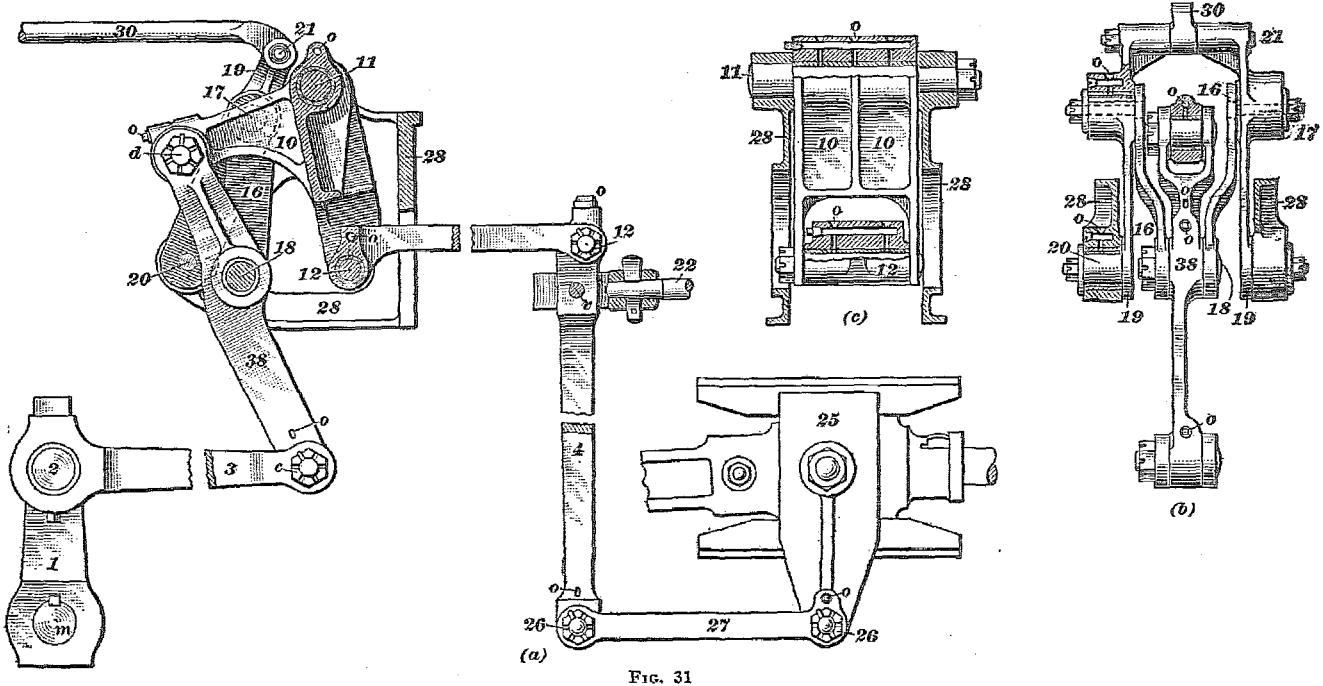

FIG. 31

main reach rod or the gear reach rod should be changed will be equal to the error found when squaring the reverse yokes. After the adjustments to the rods have been made, the gear should be in mid-position.

78. **Checking Accuracy of Work.**—When the adjustments already described have been made, the accuracy of the work should be checked by moving the bottom ends of the gear connecting-rods backwards and forwards and watching the valve to see if there is any movement, the reverse lever still being kept in the center notch. A few inches of movement on either side of the mid-position of the gear connecting-rod should not move the valve. If any movement of the valve is observed when the lower end of the rod is moved through its extreme travel, *the movement should be in the same direction* whether the rod is moved from its mid-position forwards or backwards. This means that the valve will assume the same position when the pin *c*, Fig. 31, in the bottom end of the gear connecting-rod is, say, 9 inches ahead of its mid-position, as it will when the pin *c* is 9 inches back of its mid-position. This movement will be very slight in any case and is due to the fact that the distance between the pins *18* and *d* in the gear connecting-rod does not correspond exactly to the distance between the trunnion *17* and the pin *18* in the radius bars, and, therefore, they move through a slightly different radius.

When this part of the gear has been tested and found correct, the lap-and-lead movement can be taken up. The main reach rod will not be altered again until the work of valve setting is complete, when the length of the rod is adjusted to take care of the expansion of the boiler.

79. **Correcting Lap-and-Lead Movement.**—To correct the lap-and-lead movement, connect the eccentric rods again to the gear connecting-rods and, with the reverse lever still in the center notch, rotate the main wheels forwards, and stop on all four dead centers in order. By means of the valve-stem tram take the lead, and note the amount on each dead center in the same way as was described in Art. 37. The method of determining the amount of the correction will be

precisely the same as with the Walschaert gear, but the alteration will always be made to the valve rod and never to the valve stem, as this eliminates the necessity of taking out and dismantling the valve. When the amount of correction needed has been decided on, mark the valve rods and send them to the smith for alteration. When the corrections have been made, again connect up and try over the lead on the four dead centers to make sure that the leads are equal at the front and back ports, with both the right- and the left-hand valves.

80. Setting Eccentric Crank.—The method of setting the eccentric crank is exactly the same as with the Walschaert gear, see Art. 47, except that the lines are scribed on the bottom end of the gear connecting-rod, whereas on the Walschaert gear they were scribed on the link foot.

81. Correcting Length of Eccentric Rod.—The length of the eccentric rods is corrected in exactly the same manner as explained in Art. 48.

82. Locating Stops on Reverse-Lever Quadrant. The work of locating the stops on the reverse-lever quadrant is also identical with that of the Walschaert gear, as explained in Art. 51.

83. Summary of Preliminary Operations.—The different operations necessary to set the valves with the Baker valve gear will be summarized in the same way as with the Walschaert gear, in order to emphasize the close similarity in the methods followed.

1. Ascertain the setting required. By this is meant the maximum valve travel, the amount of the steam lap, the lead, and the exhaust clearance or exhaust lap, as the case may be. The setting will vary according to the size of the locomotive and according to the class of service: passenger, freight, or switching.

2. Check up all parts of the gear with the drawings, also the port spacing and the valves.

3. Carefully assemble the gear and apply the main rods and crossheads.

4. Place the rollers under the main wheels and adjust the height of the top of the frame above the center line of the axle by means of jacks if necessary.

84. Summary of Valve-Setting Operations.—The summary of the valve-setting operations is as follows:

1. Locate the dead centers.
2. Make the port marks.
3. Check the alinement of the reverse yokes.
4. Correct the lap-and-lead movement.
5. Set the eccentric cranks.
6. Correct the length of the eccentric rods.
7. Locate the stops on the reverse-lever quadrant.

By comparing this summary with that shown in Arts. **52** and **53** relating to the Walschaert gear, it will be seen that the operations follow in exactly the same order, and that there is practically no difference in the method of squaring up the two gears.

85. Testing the Setting.—When these adjustments have been correctly made, the setting may be tested in the same way as the Walchaert gear or by placing the engine on each dead center in turn and throwing the reverse lever from the full back gear to full forward gear, at the same time holding the valve-stem tram on the valve stem to watch for any movement of the valve. The valve on the side that is on the dead center should remain absolutely stationary through the entire sweep of the lever and should show a port opening equal to the specified lead. If the gear stands this test on all four dead centers, it may be considered square, and whatever readings are required may be taken and reported. The proper adjustment should then be made to the main reach rod to take care of the expansion of the boiler as explained in Art. **63**, and the valve gear will be ready for service.

ALTERNATIVE METHOD OF SETTING

86. In the method just described for setting the Baker gear, the first method which was used for setting the Walschaert gear has been closely followed, and it will be found that the alternative method described in Arts. 64 to 70 for the Walschaert gear may be followed just as closely.

87. Preliminary Work.—The work will be started in the same way as before. First, ascertain the setting required for the locomotive, carefully check and assemble the parts of

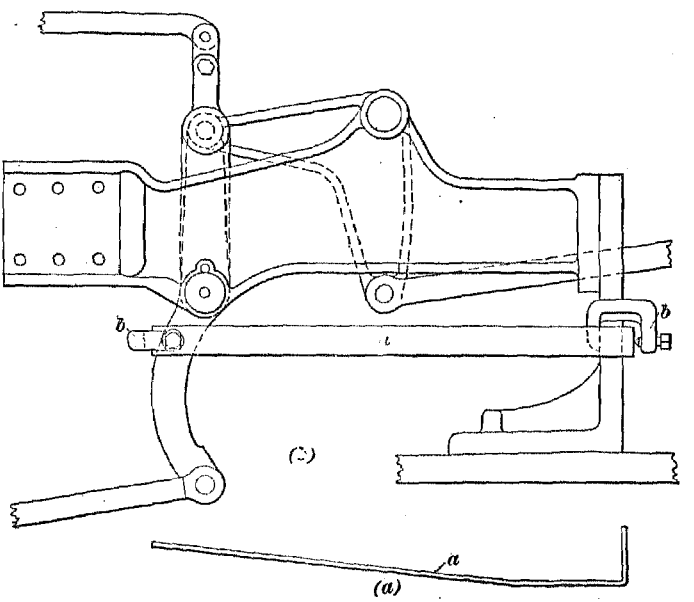

FIG. 32

the gear, place the rollers under the main driving wheels, locate the dead centers and make the port marks. The reach rod and gear reach rods will then be adjusted, if it is found necessary to correct the alinement of the reverse yokes, in the same way as in the method previously described. Then disconnect the front ends of the eccentric rods, and block both gear connecting-rods in the position they must assume when

the main crank on the same side of the engine is on either dead center; that is to say, after the gear connecting-rods are blocked in position, the reverse lever may be moved from full forward gear to full backward gear, and vice versa, without moving either valve.

A piece of flat bar iron *a* bent to suit, as shown in Fig. 32 (*a*), with a couple of clamps *b*, as shown in view (*b*), will be found useful for holding the gear connecting-rod in position.

When both rods have been blocked in this way, have the reverse lever thrown forwards and backwards, and at the same time hold the valve-stem tram on each valve stem in turn, in order to make sure that the valves remain absolutely stationary, no matter how far the reverse lever is moved. The gear connecting-rods will be left in this position until all the necessary adjustments are made to the gear.

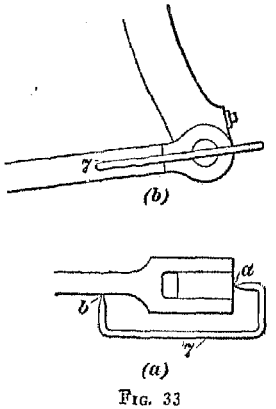

FIG. 33

88. Correcting Lap-and-Lead Movement.—The lap-and-lead movement will be corrected in the same way as before. Leave the eccentric rods disconnected and place the reverse lever, in the center notch, try the engine over on all four dead centers, and note the lead registered by means of the valve-stem tram. If corrections are necessary, take down the valve rods and mark them for alteration as before.

89. Setting Eccentric Crank.—The method followed to set the eccentric crank will be precisely the same as that outlined in the alternative method for setting the Walschaert gear. It may not be possible, however, to scribe lines around the end of the eccentric-rod fork on the gear connecting-rod in the same way as on the link foot of the Walschaert gear. Under such circumstances it will be necessary to use a special tram 7 for this operation, as shown in Fig. 33 (*a*). Before the front ends of the eccentric rods are disconnected and the gear

connecting-rods blocked as just described, make a center-punch mark at *a*, view (*a*), on the bottom end of the gear connecting-rod, and with one end of the tram 7 in the mark, scribe a line *b* on the outside of the eccentric rod close to the fork end and make a light center-punch mark on the line. View (*b*) shows the tram applied as viewed from the side. In this way it can be determined just how much the eccentric rod has to be lengthened or shortened to allow the pin exactly to enter the bushing.

90. Then turn the wheels to the nearest dead center, say the right front, and raise the front end of the right-hand eccentric rod to engage the bottom end of the gear connecting-rod. Do not attempt to put the pin in, but, holding the rod in place, again take tram 7, and, with one end in the center-punch mark *a*, Fig. 33, scribe a line on the outside of the eccentric rod in the same way as was done before disconnecting it from the gear connecting-rod. Then come to the next dead center, the left front, and raise the left-hand eccentric rod and mark it with tram 7 in the same way. Follow around to the right back dead center and again mark the right-hand eccentric rod with the tram. If this line coincides with the line that was scribed with the engine on the right front dead center, then the setting of the right-hand eccentric crank is correct. If two lines are shown for the front and back dead centers, drive the eccentric crank out or in, as the case may be, until a line scribed on the eccentric rod with tram 7 comes exactly midway between the other two lines. The eccentric crank is then in the correct position. Then come to the left back dead center and again scribe a line on the left-hand eccentric rod. Adjust the setting of the left-hand eccentric in the same way as the right-hand eccentric, if it is found necessary. If any adjustments are made in the setting of the eccentric cranks, try over a second time to make perfectly sure that they are correctly set before keying them in position, for the lines which are scribed on the eccentric rod with tram 7 with the engine on the front and back dead center must exactly coincide.

91. Correcting Length of Eccentric Rod.—The eccentric rods are the correct length if they meet the following requirements: With the gear connecting-rods fixed in their present position and the eccentric cranks correctly set, the length of the eccentric rods should be such that either of the pins which couple them to the gear connecting-rods will exactly enter the bushings when that side of the engine is on the front or the back dead center. That is, the right-hand pin should go into place, if the engine is on the right front or right back dead center; and the left-hand pin should go into place, if the engine is on the left front or left back dead center. Before the front ends of the eccentric rods were disconnected, a line *b*, Fig. 33, as explained in Art. 89, was scribed on each of them with the tram 7, and when setting the eccentric crank, lines were again scribed as explained in Art. 90. The two lines that were finally made on each rod when the eccentric setting was checked coincided with each other, or they formed only one line; and it should also be apparent that if the line made at the final checking of the eccentric setting coincides with the line *b*, which was scribed before the rods were disconnected, then the length of the eccentric rod is correct and the pin will go into place when the engine is on the front or the back dead center on that side, without alteration of the length of the rod.

92. If the line made on each rod does not coincide with the line *b* which was made before the rod was disconnected, the amount the rod has to be lengthened or shortened will be the distance between this line and the line *b*. If the line falls back of the line *b*, the rod will need to be shortened, and if it falls ahead of line *b*, it will need to be lengthened. If the lines scribed at the final checking of the eccentric setting do not coincide with lines *b*, they should be center-punched lightly and the rods marked for lengthening or shortening and sent to the smith. If the eccentric rods have to be altered, leave the gear connecting-rods blocked in position until the alterations have been made so that the length of the rods may be checked again before they are finally applied.

93. Making Adjustments at Same Time.—As in the case of the Walschaert gear, the different adjustments can be tested simultaneously. For example, when checking the lap-and-lead movement, stop on each of the four dead centers to take the lead, at the same time raise the front end of the eccentric rod on each dead center and mark it to check the eccentric setting. When the eccentric setting is corrected, the required adjustment to the eccentric rods is known and then all parts that require alteration can be taken down and sent to the smith. After all adjustments have been made and checked, the gear connecting-rods are released from their blocking, the gear assembled, the location of the stops on the reverse-lever quadrant checked, and whatever readings are required may be taken and reported.

SETTING THE VALVES WITH STEPHENSON VALVE GEAR

94. Introduction.—Although the Stephenson valve gear has been almost entirely superseded on the modern locomotive, there are many thousands of locomotives still in service equipped with this gear, and these will have to be maintained and set for many years to come. With the Walschaert and Baker gears, the valve derives its motion from the main crosshead and the eccentric crank. With the Stephenson gear, the valve derives its motion solely from the eccentrics on the main axle. The gear is located between the frames, and four eccentrics are keyed to the main axle, two for forward motion and two for backward motion.

When the locomotive is in full forward gear, the movement of the valves is produced entirely by the forward-gear eccentrics, and when in full back gear by the back-gear eccentrics. In any intermediate position of the reverse lever the movement is derived from a combination of the movement of the forward-gear and the back-gear eccentrics.

95. Names of Parts.—In Fig. 34 is shown the Stephenson valve gear as arranged for an outside-admission valve and

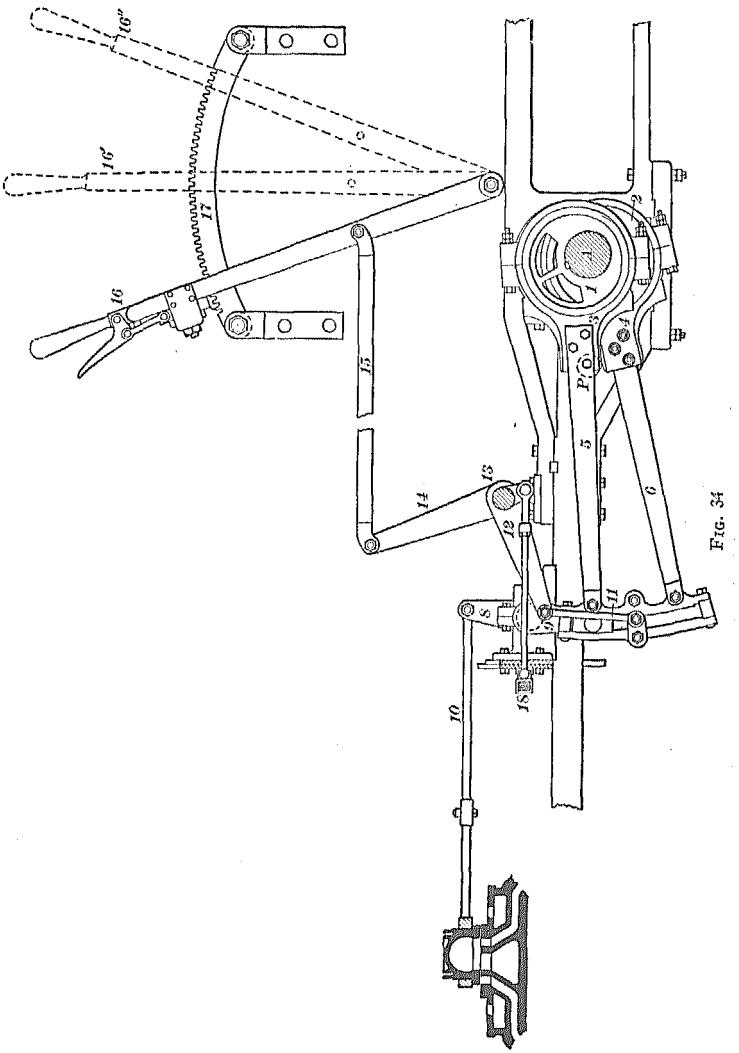

FIG. 34

indirect motion. The names of the principal parts are as follows: *1*, the forward-motion, or go-ahead eccentric; *2*, the backward-motion or back-up eccentric; *3*, the go-ahead eccentric strap; *4*, the back-up eccentric strap; *5*, the go-ahead eccentric rod or blade; *6*, the back-up eccentric rod or blade; the link with a link saddle; the link block; the rocker with two arms, the upper rocker-arm *8* and the lower rocker-arm, *9*; *10*, the valve rod; *11*, the link hanger; *12*, the reverse-shaft arm; *13*, the reverse shaft or tumbling shaft; *14*, the upper reverse-shaft arm; *15*, the reach rod; *16*, the reverse lever; *17*, the quadrant; and *18*, the counterbalance spring.

96. Preliminary Operations.—First ascertain the setting required for the locomotive under consideration; that is to say, the maximum valve travel, the steam lap, the lead and the exhaust clearance, or exhaust lap, as the case may be. The valve setting will be different from that required with a constant-lead gear, as the Stephenson gear is commonly set with no lead or a very slight lead, or sometimes slightly blind in full gear. The valve events in running position will then be approximately the same as with the other gears, because the lead and the preadmission increase considerably on notching up the reverse lever to the shorter cut-offs. The parts of the gear should be very carefully checked with the drawings, particular attention being paid to the throw of the eccentrics, the radius of the link slots, the back set of the link-saddle pins, the alinement of the reverse-shaft arms, the length of the link hangers, the port spacing, and the valves. If there should be a slight error in the length of the valve rods or eccentric rods, do not alter them, as they will be taken care of as the work of valve setting proceeds.

97. Assembling the Gear.—Carefully assemble the valve gear in accordance with the arrangement drawing, and see that all parts fall into line without forcing or springing. This is particularly important with the Stephenson gear, as the frictional surfaces are large and the surface speeds much higher than in any of the outside gears. If the gear is not assembled in such a way that it will run smoothly, it will be

impossible to get good service from it. Moreover, it will be impossible to make certain that the valves are correctly set. The reason is that, if the parts of the gear are binding instead of moving freely, the movement of the valve will be jerky instead of smooth when the wheels are being rotated by the rollers, and true readings are not possible under such circumstances.

98. If an eccentric rod requires setting to the right or to the left a small amount, in order that the fork end may lead fairly on to the link, a tool *a*, shown in Fig. 35, will be found useful, as the rod may then be set without taking it down. It will be noticed that this tool is exactly the same in

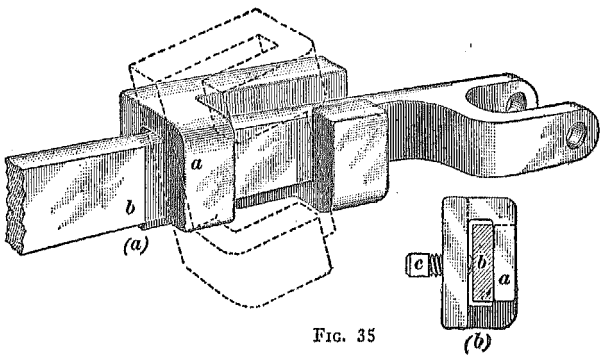

FIG. 35

principle as an ordinary *Jim Crow*, which is used by track men for bending or straightening rails. Instead of fitting over one side of the rod *b*, view (*a*), however, it is generally made so that it has to be twisted to the position shown by the dotted lines to put it on or take it off. When made in this way, there is no danger of it moving when the setscrew *c*, view (*b*), is being tightened, as the pull on the wrench tends to hold it firmly in place.

99. If a rod requires slight twisting to enable the pin to enter the hole fairly, a tool such as is shown in Fig. 36 may be used to give it the required twist. These tools should, however, only be used to make slight adjustments. If the

set or twist required is considerable, the rod should be taken down and heated. The use of these tools is not confined to

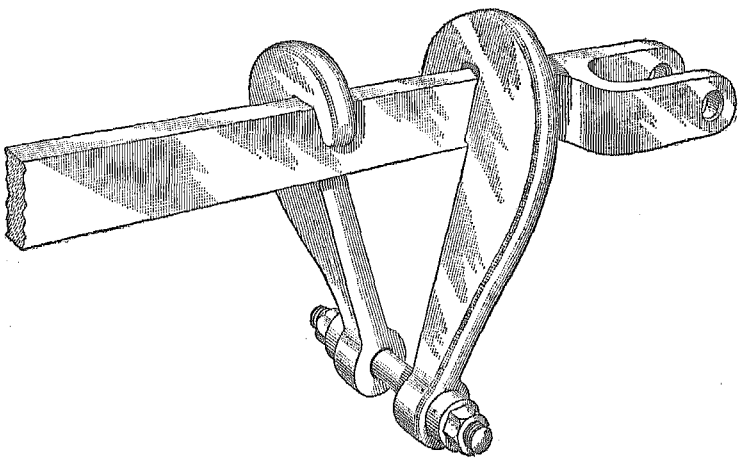

FIG. 36

the Stephenson gear, and they will be found useful when such adjustments have to be made on other types of gears.

After the gear has been carefully checked and assembled, the next step is to apply the main rods and crossheads, place the

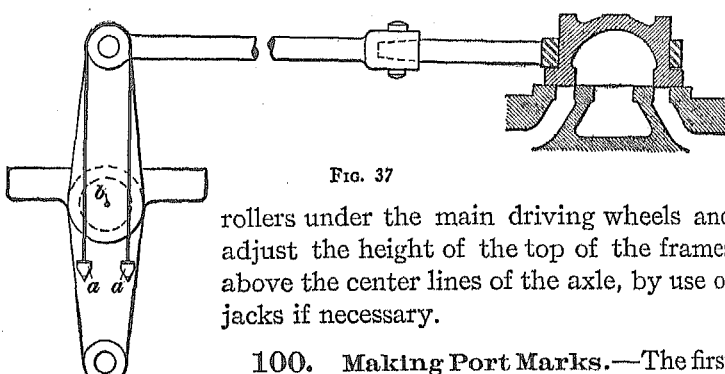

FIG. 37

rollers under the main driving wheels and adjust the height of the top of the frames above the center lines of the axle, by use of jacks if necessary.

100. Making Port Marks.—The first step in the actual setting of the valves is to make the port marks. These are made as explained in Art. 28.

101. Correcting Length of Valve Rod.—To ascertain whether the valve rod is of the correct length, set the rocker

in such a position that the outside arm which is connected to the valve rod is exactly vertical. This position is tested by means of a plumb line, as shown in Fig. 37. The line has a plumb bob *a* or a nut attached to each end of it, and is hung over the top pin of the rocker-arm as shown. The rocker must then be adjusted, so that the two parts of the line are at equal distances on each side of the lathe center *b*.

Next take the valve-stem tram, and see if the valve is in central position. If it is, the tram point will enter the center port mark. If the valve is in central position, the valve rod is of the correct length; if it is not, the valve rod needs to be lengthened or shortened by an amount that will place the valve in its central position. If the rods need to be altered, mark them for alteration as explained in Art. 42, and send them to the smith.

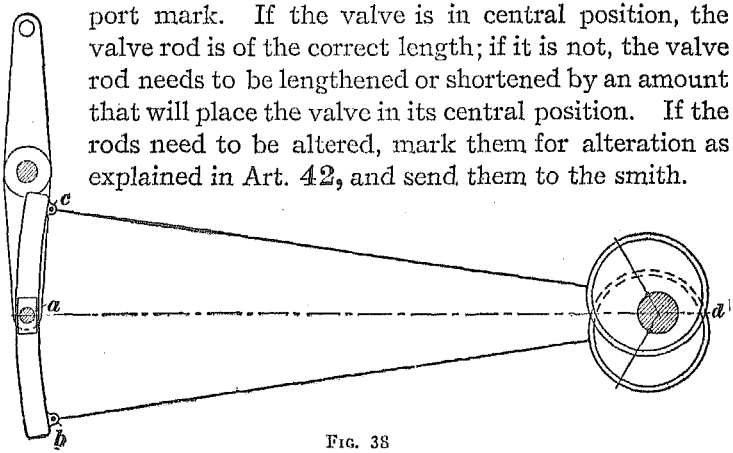

FIG. 38

102. Dead Centers.—Locate the dead centers, as has already been explained in Art. 25.

103. Checking Length of Reach Rod.—To check the length of the reach rod, place the reverse lever in the middle notch of the quadrant, rotate the wheels, and stop on any dead center. This will bring the link on that particular side square with the center line of motion *a d*, Fig. 38. Then measure the distance that the link-block pin *a* on this side is from the forward-gear and back-gear eccentric-rod pins *c* and *b*. The link-block pin *a* should be exactly midway between the two eccentric-rod pins, and if the measurements show that this is the case, the length of the reach rod is correct. If the distances are unequal, adjust the reach rod so as to make it of the correct length.

Before going further, it will be advisable to check the left-hand link in the same way on a left-hand dead center. This will show whether the alinement of the reverse shaft and link hangers is correct, and may save trouble later on.

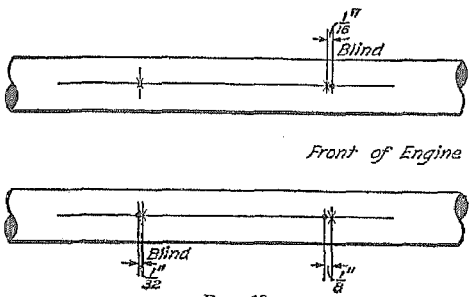

FIG. 39

104. Correcting Length of Eccentric Rods. To correct the length of the eccentric rods, place the reverse lever in full forward gear, rotate the main wheels forward, stop on all four dead centers in turn, and take the lead on each center by means of the valve-stem tram. Suppose, with outside-admission valves, that these leads are as shown in Fig. 39, or right front, $\frac{1}{8}$ inch lead; left front, $\frac{1}{16}$ inch blind; right back, $\frac{1}{32}$ inch blind; left back, line and line. The dots on the valve stems represent the port marks and the crosses represent the lead marks.

The length of the forward-gear eccentric rods must now be adjusted to equalize the lead at the front and the back ports. The rule used to determine how far the valve has to be moved to equalize the lead is given in Art. **39.** Apply the rule to the right-hand valve stem, and $\frac{1}{8}+\frac{1}{32}=\frac{5}{32}\div 2=\frac{5}{64}$ inch, the correction required. On the left-hand valve stem the correction required will be $\frac{1}{16}\div 2=\frac{1}{32}$ inch.

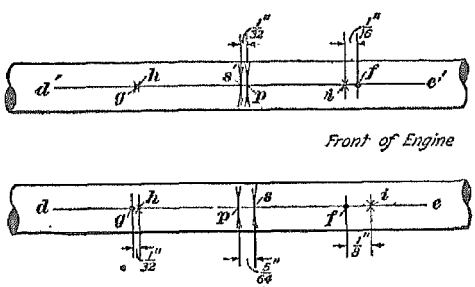

FIG. 40

The correction can also be found as explained in Art. 41 and as shown in Fig. 40. Find the center points p between

the front port marks f and the back port marks g. Then find the point s, midway between the lead marks h and i on the right-hand valve stem and the point s' midway between the lead marks h and i on the left-hand valve stem. The distance between p and s, or $\frac{5}{64}$ inch, is the correction required on the right-hand valve stem, and the distance from p to s', or $\frac{1}{32}$ inch, the correction on the left valve stem.

105. On the right side the lead has to be decreased at the front port and increased at the back port. So with outside-admission valves the eccentric rod must be lengthened if the motion is direct and shortened if the motion is indirect. With

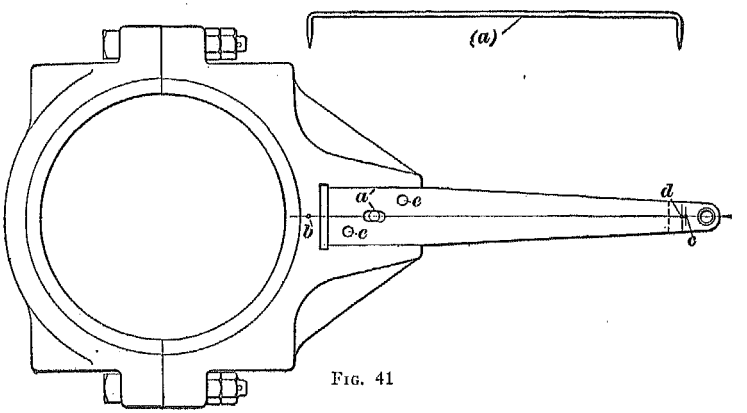

FIG. 41

inside-admission valves the rod must be shortened, if the motion is direct and lengthened if the motion is indirect. The amount the rod has to be altered depends on how the rocker-arms are proportioned; if both arms are of equal length, the alteration to the rod will be equal to the correction required at the valve, or $\frac{5}{64}$ inch in this case, but where the outside and inside arms are of different lengths, the amount of alteration will vary accordingly.

106. Assume that the locomotive has outside-admission valves and that the motion is indirect, as shown in Fig. 34. The right forward-gear rod will have to be shortened enough to

move the right-hand valve forward $\frac{5}{64}$ inch, and the left forward-gear rod lengthened enough to move the left-hand valve back $\frac{1}{32}$ inch. This is a comparatively simple matter, as one of the bolt holes a' in the front half of the eccentric strap, Fig. 41, is elongated to permit of a temporary adjustment of the rods, while the work of valve setting is proceeding. The eccentric rods are held by one bolt through this elongated hole until the valves have been set. So it is only necessary to slacken the nuts and move the rods on the straps the amount necessary to equalize the lead at the front and the back ports. Therefore, slide the right-hand rod backwards on the strap and the left-hand rod forwards on the strap the required amount, and again tighten the nuts. The amount the valve is moved by the change in the length of the rods is checked by the valve-stem tram.

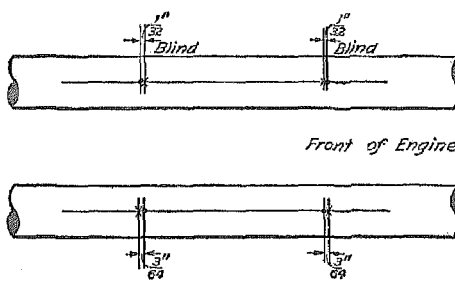

FIG. 42

Now try the engine over again, and take the lead on all four dead centers. If the adjustments have been made correctly, the readings should be as shown in Fig. 42, or as follows: Right front, $\frac{3}{64}$ inch lead or $\frac{1}{8}-\frac{5}{64}$; left front, $\frac{1}{32}$ inch blind or $\frac{1}{16}-\frac{1}{32}$; right back, $\frac{3}{64}$ inch lead or $\frac{5}{64}-\frac{1}{32}$; left back, $\frac{1}{32}$ inch blind. If these readings are obtained, the eccentric rods are the correct length, because the readings are the same at the front and the back ports on both the right- and the left-hand sides. However, the leads are not equal on both sides and the next step will be to set the eccentrics to give the specified lead on both sides of the engine.

107. Setting Go-Ahead Eccentrics.—The go-ahead eccentric is set before the reverse lever is moved from full forward gear. It will be supposed that line and line in full gear is specified. Then it is apparent that the lead must be decreased on the right side and increased on the left side, as

the last reading taken showed a lead of $\frac{3}{64}$ inch on the right side and $\frac{1}{32}$-inch blind on the left side.

To increase the lead, the angle of advance of the eccentric must be increased, and to decrease the lead the angle of advance must be decreased. The angle of advance is always in the direction of rotation and, therefore, to increase the lead in forward gear, the go-ahead eccentric *1*, Fig. 34, must be moved around the axle in the same direction as the axle rotates when running ahead, and in the opposite direction to decrease the lead. To increase the lead in back gear, the back-up eccentric *2* must be moved around the axle in the same direction as the axle rotates when running backwards, and in the opposite direction to decrease the lead. Therefore, the right go-ahead eccentric must be moved on the axle in the direction in which it rotates when running backwards in order to decrease the lead, and it will have to be moved just far enough to bring the valve to a line and line position when the engine is on the dead center.

First, place the right side of the engine on a dead center, say the right front. Then move the right go-ahead eccentric back on the axle until, as shown by the valve-stem tram, the valve is just on the point of admitting steam to the front port. Tighten the eccentric temporarily and rotate the wheels backwards far enough to take up all lost motion, and come ahead again and stop on the right front dead center. Then take the valve-stem tram, and, if it exactly enters the front port mark, rotate the wheels to the back dead center and make sure that the valve-stem tram exactly enters the other port mark. If not quite correct at the first attempt, adjust the eccentric further and then adjust the left-hand eccentric in the same way. When the eccentrics are correctly set, tighten the setscrews well to prevent them from shifting while the locomotive is being tried over.

108. Adjusting Back-Gear Rods and Eccentrics. Having adjusted the forward-gear eccentric rods and eccentrics and temporarily fixed them in position, move the reverse lever to full back gear and, rotating the main wheels backwards,

adjust the back-gear rods and eccentrics in the same way, until a zero reading is obtained on all four dead centers. If the required setting calls for a slight lead or for the port slightly blind in full gear, instead of line and line, the procedure will be exactly the same; it is merely a question of setting the eccentrics to give more or less lead.

The engine is now square so far as the lead is concerned, and if the valve gear is well designed, the other valve events will fall within very close limits and should be approximately square all around. It is the regular practice when setting the Stephenson gear to check the cut-off in running position and to correct it if necessary, but before doing this, the valve travel should be checked to make sure that both valves have the same travel.

109. Checking Valve Travel.—The valve travel is checked in the same manner as explained in Art. **51**, or as follows: With the reverse lever in full forward gear, rotate the wheels forwards for a complete revolution, and by means of the valve-stem tram note the full travel of the right-hand valve, then repeat the process and note the full travel of the left-hand valve. The travel should be the same for both valves and should correspond with the maximum valve travel specified. If the travel of both valves is alike, but does not correspond to the maximum travel specified, adjust the stop-pin in the reverse-lever quadrant in the same way as described in Art. **51**. If the right-hand valve has a different travel from the left-hand valve, it will be necessary to make them alike.

Provided that the throw of all eccentrics, the alinement of the reverse shaft and arms, and the length of the link hangers have been carefully checked, there should be no variation found in the valve travel. If there is a difference, it will have to be corrected by raising the link on the side with the longer travel. It may be possible to do this by inserting a liner under the reverse-shaft bearings, but, if not, a link hanger will have to be taken down and lengthened or shortened as required.

110. If there should happen to be a considerable variation in the travel of the two valves, no alteration should be made until the cause of the trouble has been located, as it is quite certain that an error of some kind has been overlooked when checking up the parts. It may be that the throw of an eccentric is wrong, or it may be the length of a link hanger, the alinement of the reverse shaft, the length of a rocker-arm, or the location of a rocker box. If such an error has been overlooked, it should be found and corrected. When the valve travel has been corrected in full forward gear and the stop-pin located in the reverse-lever quadrant, pull the reverse lever into back gear and locate the other stop-pin in the quadrant.

111. Checking the Cut-Off.—The following explains how to check the cut-off: Place the reverse lever in the running position for forward gear. This position will vary according to the type of locomotive. The running cut-off for passenger locomotives is generally taken at one-quarter stroke, for fast-freight locomotives at one-third stroke, and for slow-freight locomotives at one-half stroke. Assume a passenger engine with a 28-inch stroke; the object will be to make the valves cut off the admission of steam to the cylinders just 7 inches from the beginning of both the forward and the backward strokes of the piston on both sides of the engine. First, rotate the wheels forwards until one crankpin has gone by a dead center far enough to move the crosshead 7 inches from its extreme position. For example, suppose that the right crankpin has gone by the back dead center far enough to move the crosshead 7 inches ahead of the position it assumed when on the back dead center. Then stop the wheels in this position, move the reverse lever until the valve is just closing the back port to steam, and drop the lever latch into the nearest notch. Then rotate the wheels back far enough to take up all lost motion and come forwards again, and hold the valve-stem tram on the valve stem and watch for the port to close. When the tram exactly enters the port mark, stop the wheels and measure the distance of the

crosshead from the beginning of the stroke; if it is anything between $6\frac{1}{2}$ inches and $7\frac{1}{2}$ inches, the position of the lever will be correct for a try over. If the crosshead has traveled farther than $7\frac{1}{2}$ inches, pull the lever up a notch toward the center, and if less than $6\frac{1}{2}$ inches, drop the lever down a notch and try again.

When the reverse-lever latch has been located in the proper notch rotate the wheels forwards, and after each dead center has been passed, hold the valve-stem tram on the valve stem (right or left according to which dead center has just been passed) and watch for the closing of the port. When the point of the tram exactly enters the port mark, stop the wheels and measure on the guide bar the distance the crosshead has traveled since it was on the dead center. Note this distance for the front and back ports on both sides of the engine.

112. If the gear has been well designed, the cut-offs just measured will be very nearly equal, but if they are not, they should be equalized by changing the length of the back-gear eccentric rods the amount necessary to obtain the desired result. This will throw the valves out of square in back gear, but the back gear is of minor importance compared with the running position forward.

It is impossible to lay down a rule of thumb for this part of the gear adjustment, but experience shows that even a poorly designed Stephenson gear can be set to give a good steam distribution in running position by sacrificing correct distribution in the other positions of the reverse lever.

When the back-gear rod has been adjusted to square the cut-off in running position forward, it will be found that the lead will be thrown slightly out of square, and it will be necessary to make a slight adjustment of the forward-gear rod to correct the lead. By experimenting in this way and making adjustments as required, a very good steam distribution may be obtained in the running position of the lever.

113. Changing Length of Eccentric Rods.—When the cut-off has been satisfactorily adjusted, the valve setting

is complete and the eccentric rods are now marked for alteration, if necessary. If the change in length is very slight, reaming the holes and fitting new turned bolts may be the best way to make the alteration, but if the change in length is considerable, the alteration required should be marked on the rods by use of a tram such as is shown at *a*, Fig. 41. First make a center-punch mark on the strap at *b*. Before slackening the bolt which has held the rod while the valves were being tried over, take the tram *a*, and with one end of it held in the center-punch mark *b*, scribe a line on the eccentric rod at *c* near the fork end. Next slacken the bolt which is holding the rod to the strap and move the rod to such a position that the fitted bolt will enter the holes *e* and temporarily tighten the nut. Again take the tram *a* and scribe another line *d* on the rod, then take down the rod and make light center-punch marks on the lines *c* and *d*, and chalk the word *lengthen* or *shorten* on the side of the rod and send it to the smith. It will be noticed that in the case shown in Fig. 41 the rod will have to be shortened because the line *d* falls back of the line *c*. When the rod is returned from the smith and bolted into place, its length can be checked by holding one end of the tram in the center-punch mark *b*, when the other point should exactly enter the mark *c*.

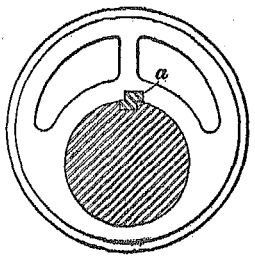

FIG. 43

Treat all the rods which require alteration in the same way and then mark the eccentric keyways on the axle, if the keyways are not already made. If the setting of an old eccentric has had to be changed, the keyways in the axle and in the sheave will not coincide with each other, and in this case make a step key *a*, Fig. 43, offset the proper amount to give the new setting.

After the eccentrics have been permanently fixed in place, the rods applied and bolts properly fitted, the work of valve setting is complete, and whatever form of report is required, may be made.

114. Summary of Preliminary Operations.—A summary of the preliminary operations involved in setting the Stephenson gear follows:

1. Ascertain the setting that is required; that is to say, the maximum valve travel, the steam lap, the lead, and the exhaust clearance or exhaust lap, as the case may be.
2. Check up all parts of the gear with the drawings, also the port spacing and the valves.
3. Carefully assemble the gear and apply the main rods and the crossheads.
4. Place the rollers under the main wheels and adjust the height of the top of the frame above the center line of the axle, by means of jacks if necessary.

115. Summary of Valve-Setting Operations.—A summary of the valve-setting operations follows:

1. Make the port marks.
2. Correct the length of the valve rod.
3. Locate the dead centers.
4. Check the length of the reach rod and alinement of reverse-shaft arms and link hangers.
5. Correct the length of the eccentric rods.
6. Set the eccentrics.
7. Check the valve travel and locate the stops on the reverse-lever quadrant.
8. Check the cut-off in running position forward gear.

The sequence of the operations may be changed to some extent. With experience, it will be found that some of them may be made simultaneously, thus cutting down the time required to make the setting. However, in order to make the explanation as clear as possible, the various steps have been described separately.

116. Conclusion.—For the sake of simplicity it has been assumed that all the gears dealt with were equipped with a hand reverse lever, but there is absolutely no difference in the method of setting the valves whether the locomotive is equipped with the hand lever, screw, or power reverse. It is merely a question

of placing the reverse gear in the position required for the particular operation in hand and locating the stops on the quadrant or guides, as specified.

To set locomotive valves well and in a reasonable space of time, requires experience; but, if a person gets a good grasp of the principles which have been outlined and afterward should have an opportunity of working with a good valve setter for a while, he ought soon to become efficient.

Valve-setting methods known as *trailing* should not be used if facilities are available for following the methods outlined in this lesson, because there is no work on a locomotive where accuracy pays better than in setting the valves.

TRAILING METHOD OF VALVE SETTING

INTRODUCTION

117. The various operations that are performed when setting the valves by the method already described, require that the engine frequently be placed on a dead center; hence this method may be called the dead center method of valve setting. The reason for spotting the engine on a dead center is to obtain equal leads at all four ports, and lead is measured only on the dead centers. The results obtained from the dead center method of valve setting are as accurate as the design of the valve gear will permit.

However, there is still to be considered the question of the locomotive that may be located at a point where no facilities for taking the dead centers are available, or where it is impossible to take the engine out of service for the time required to set the valves in accordance with the method already outlined. Under such conditions what is called the trailing method of valve setting is employed, and, although the valves can be set more quickly than by the dead center method, they cannot be set so accurately.

118. Setting the valves without taking the dead centers is called trailing because the work is done by moving the engine

by its own steam or by another engine. As the lead cannot be measured without taking the dead centers, the object sought in the trailing method of valve setting is to obtain equal port openings in the running cut-off at the front and back ends of the cylinders on both sides of the engine and in both motions.

Owing to the difficulty of stopping the engine at the proper points, the cut-offs are not ordinarily checked when the trailing method of valve setting is employed.

When the trailing method is used, only the eccentric rods and the valve rods are changed, although, should it be found that the bushings in the steam chests have shifted, it will be necessary to correct the valves. To set the eccentric crank properly without taking the dead centers is impossible. It is always preferable to pull the engine by means of another engine when setting the valves by the trailing method, because, when the engine is run under its own steam, any creeping of the power reverse gear causes confusion while the readings are being taken. Also, when making the port marks, any leakage of steam makes it difficult to line up the steam rings of the valve with the ports after the peep-hole plugs are removed.

PRELIMINARY OPERATIONS—WALSCHAERT VALVE GEAR

119. Checking Gear Parts.—Prints of the parts of the gear are not usually available at points where the trailing method of setting the valves is employed, hence no check can be made of the gear parts.

120. Checking Length of Reach Rod.—The design of the Walschaert valve gear is such that, in mid-gear, the arm of the reverse-shaft crank to which the main reach rod is connected is vertical and the link block is in the center of the link. With this fact known, the length of the main reach rod can be checked accurately. If the engine is cold, move the gear by a bar until the particular arm of the reverse-shaft crank just mentioned is plumb, then note the position of the center mark on the crosshead of the power reverse gear relative to a mark taken midway of the reverse-gear stroke. The crosshead mark should come to the rear of the midway mark by an amount

equal to the allowance made for the expansion of the boiler, usually about $\frac{1}{2}$ inch. If less or more than the expansion allowance, the reach rod should be adjusted to bring the marks the proper distance apart. If the engine is under steam, the marks should coincide if the reach rod is the correct length.

With the type of power reverse gear that does not use guides, the midway mark on the piston should come opposite the end of the gland when the engine is under steam, if the length of the reach rod is correct. The cab reach rod should also be adjusted to bring the reverse lever the proper amount either to the rear of mid-position if the engine is cold or to mid-position if the engine is under steam. The main reach rod is adjusted by screwing the jaws off or on as required, and then tightening the jam nuts.

121. Checking Radius-Rod Hangers.—With the arm of the reverse-shaft crank still plumb, disconnect the eccentric rod on the right side from the link and swing it forward and back of its mid-position. If the radius rod moves, the radius-rod hanger is either too short or too long. If the rod moves in the same direction as the link foot, the hanger is too long; if in the opposite direction, the hanger is too short. Now tram the hanger from some convenient point on the engine, and then bar the radius rod up or down until there is no movement of the rod when the link is moved. Then tram again; the distance between the tram marks will be the alteration that is necessary. This change when made will again bring the arm of the reverse-shaft crank to a vertical position. Check the length of the hanger on the left side by swinging the link and tramming as already described, first plumbing again the arm of the reverse shaft crank that was moved out of plumb when checking the length of the right radius-rod hanger.

If the left hanger is found to require a change in order to obtain a still valve, both hangers can now be taken to the shop at the same time for alterations.

If the engine is under steam, the power reverse gear must be blocked to prevent it from creeping and moving the arm out of plumb while the link is being moved. Then the air

must be shut off from the gear and the blocking removed, before the radius rod can be moved with a bar.

A different procedure must be followed to obtain a still valve if the rear end of the radius rod is carried in a slip block and the rod moves when the link is swung when the upper arm of the reverse-shaft crank is vertical. The forked arm of the crank that carries the slip block is frequently found to be sprung. In a case of this kind, the vertical position of the arm with the reverse lever in mid-gear must be sacrificed in order to obtain a still valve.

One method that is used, assuming that the trouble is on the right side, is to block the crank on the left side, and heat the shaft on the right side near the box, protecting the box itself with asbestos. Then, by jacking the crank on the right side, the reverse shaft can be twisted enough to bring the crank to the correct position to obtain a still valve. The foregoing operation will cause the link block to occupy a slightly different position in the link in one gear than in the same position of the reverse lever in the other gear.

122. Checking Steam-Chest Bushings and Making Port Marks.—The port marks are made in the usual manner, then the distance between these marks should be measured to ascertain whether the steam lap is correct. This dimension should be equal to twice the specified steam lap. The purpose of this check is that, for reasons not fully understood, the steam-chest bushings or cages, although secured by studs, almost invariably move from $\frac{1}{16}$ inch to $\frac{1}{4}$ inch farther apart after the engine has been in service for some time. The effect of this movement of the bushings is to increase the steam lap or the amount the steam rings overlap the ports; and this condition is remedied by pulling the valve and lengthening the front end of the spool, by welding, the amount the bushings have moved. However, this work is not done until the valve-setting operations are completed, when all corrections are made at one time. As will be explained farther on, allowance will be made for the amount the steam lap has been increased by the movement of the bushings, by adding this amount to

the port openings obtained at the front port when the engine is trailed.

It is assumed that the valve setter knows the steam lap that is used with the various types of locomotives on his road.

123. Checking Eccentric Crank.—If the crank circle prescribed by the design is known and if a gauge similar to that shown in Fig. 11 (*a*) is available, it can be determined whether the eccentric crank is set to give the correct valve travel. However, this would not always imply that the crank is set correctly with respect to the center line of motion of the

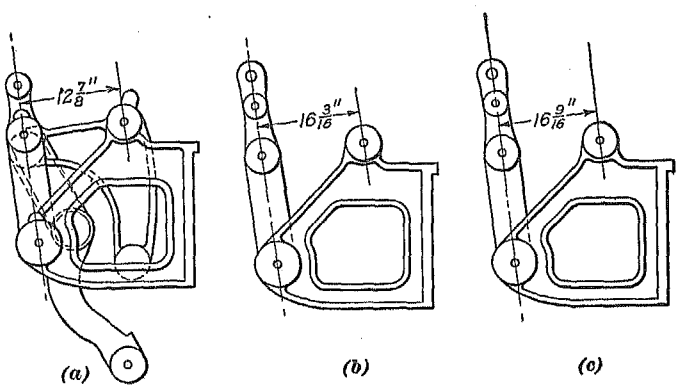

FIG. 44

eccentric rod. This setting of the crank can be obtained only when the dead centers are taken as explained in Art. 47. Owing to lack of data or the proper gauge, it is usually not possible to make any check of the eccentric cranks at points where the trailing method is employed.

PRELIMINARY OPERATIONS—BAKER VALVE GEAR

124. Checking Length of Main Reach Rod and Gear Reach Rod.—The design of the Baker valve gear is such that in mid-gear the reverse-shaft arm is vertical and the reverse yoke is in central position. In this position of the reverse yoke the distance between the center of the radius-bar bearing

pin in the reverse yoke and the center of the frame bearing pin in the bell-crank is $12\frac{7}{8}$ inches with the standard gear, $16\frac{3}{16}$ inches with the long travel gear, and $16\frac{9}{16}$ inches with the long lap gear, as shown in Fig. 44, views (*a*), (*b*), and (*c*). Therefore to check the length of the gear reach rod on, say, the right side, plumb the reverse-shaft arm, which also places the reverse yoke in a central position. Then, if the gear reach rod is the correct length, the two points already named, when trammed, will give the distances specified. If not the correct length, the dimensions will be less or more than those given. To make the required correction, tram from some point on the boiler to the gear reach rod, then move the reverse yoke until the dimension required is obtained and tram again. The distance between the tram marks will be the alteration required to the rod. Check the other gear reach rod in the same way.

However the main reach rod is checked for length, first, as already described with the Walschaert valve gear, after the reverse-shaft arm is plumbed. The steam-chest bushings are checked and the port marks are made as already explained.

IDENTIFYING PARTS REQUIRING CORRECTION FROM VALVE-ROD READINGS

125. What Readings Indicate.—The main reach rod and the radius-rod hangers have been corrected for length, the port marks have been made, and any movement of the valve cages has been noted. The main reach rod and the gear reach rods, if the Baker gear is used, have also been corrected and any correction on the valve spools for the movement of the cages has been noted for both gears. The next step is to trail the engine in the running cut-off in both gears, but before this is done it will be explained how it is possible to tell the part or parts that required to be corrected, from the readings obtained on the valve rod when the engine is trailed.

The readings, when taken in both gears and when correctly interpreted, will show whether the valve rod or the eccentric rod or both require to be corrected. Also, the readings will show whether the eccentric crank is set properly, although an

error in the crank will not be considered in the first part of this discussion. It will be assumed that the valve rod and the eccentric rod are the parts found to require correction.

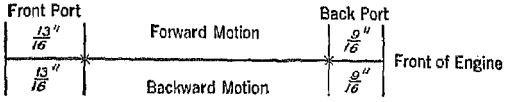

FIG. 45. Valve-Rod Error

126. Valve-Rod Error.*—A valve-rod error is indicated when the sum of the port openings at one port in both gears is not equal to the sum of the port openings at the other port in both gears. Thus, a valve-rod error is indicated in Fig. 45 in which $\frac{9}{16}$ plus $\frac{9}{16}$ is not equal to $\frac{13}{16}$ plus $\frac{13}{16}$. In this illustration as well as in others of a similar kind, the port marks are indicated by an x.

127. Eccentric-Rod Error.—An eccentric-rod error is indicated when the sum of the port openings in both gears, taken diagonally, is not equal. Thus an eccentric-rod correction is required when the readings appear as in Fig. 46 because $\frac{3}{8}$ plus $\frac{3}{8}$ does not equal $\frac{1}{2}$ plus $\frac{1}{2}$.

128. Combined Valve-Rod and Eccentric-Rod Error. An error will be indicated in both the valve rod and the eccentric rod when the port openings in both gears are not equal when added either vertically or diagonally. A combination of a valve-rod error and an eccentric-rod error is shown in Fig. 47.

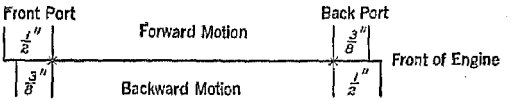

FIG. 46. Eccentric-Rod Error

129. Eccentric-Crank Error.—When the error is in the position of the eccentric crank alone, the sum of the port openings at the front and back ports in forward gear will not be equal to the sum of the port openings in back gear. In this case the port openings are added horizontally. The readings given in Fig. 48 show that the eccentric crank requires an

*Also referred to as valve stem.

adjustment in position because $\frac{7}{8}$ plus $\frac{7}{8}$ is not equal to $\frac{5}{8}$ plus $\frac{5}{8}$.

130. Combined Valve-Rod, Eccentric-Rod, and Eccentric-Crank Error.—Errors in the valve rod, in the eccentric rod, and in the position of the eccentric crank are

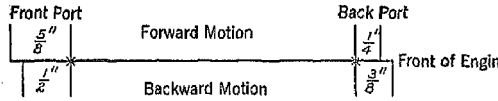

FIG. 47. Combined Valve-Rod and Eccentric-Rod Error

indicated when, as in Fig. 49, the port openings in both gears are unequal when added either vertically, diagonally, or horizontally.

VALVE-SETTING OPERATIONS

131. Obtaining Port Openings.—The port openings should be equalized in the cut-offs prescribed by the regulations of the railroad company; the running cut-off is generally selected. To locate the reverse lever in the approximate position to give the specified cut-off of 25 per cent., forward gear, move the engine ahead until the crosshead has moved back this per cent of the stroke. This would be 7 inches with a 28-inch stroke. The reverse lever is only approximately in the 25 per cent. cut-off because the valve gear is out of adjust-

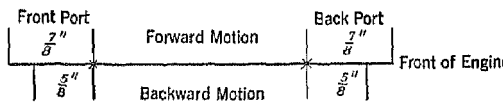

FIG. 48. Eccentric-Crank Error

ment. It is only when the gear is square that the position of the reverse lever can be located accurately in this manner. Then, with the crosshead in the position just mentioned, move the valve by drawing the reverse lever up until the tram coincides with the proper port mark on the valve stem. This will be the approximate position of the reverse lever for the 25 per cent. cut-off. Next, move the engine forward and begin

tramming the valve stem at about the time the crankpin passes the center for the port that is being considered. The tramming should be done at all four ports and should be performed twice to see whether the same lines are obtained; if not, the power reverse gear is creeping. The distances between

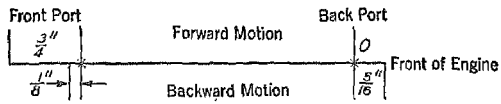

FIG. 49. Combined Valve-Rod, Eccentric-Rod, and Eccentric-Crank Error

the port marks and the marks indicating the point where the valve reverses its movement are the port openings for the 25 per cent cut-off. The measurements are put down on paper as they appear on the valve stem; those on the right valve rod are assumed to be as shown above the horizontal line in Fig. 50. The readings on the left side are similarly recorded but are not shown here.

Next, locate the approximate position of the reverse lever in the 25 per cent. cut-off backward motion in the same manner as in forward motion, then move the engine backward and after rechalking the valve rod without disturbing the port marks, obtain the port openings for backward motion. The readings on the valve stem on the right side are assumed to be as shown below the horizontal line in Fig. 50. The readings on the left side are similarly listed but are here omitted.

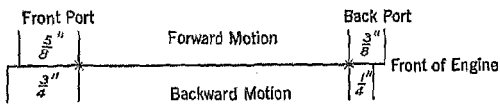

FIG. 50

After both sides are trailed, the valve travel should be measured by taking the distance between the extreme points on the valve rod on each side, and these measurements should be equal. This is a check on the eccentric cranks also, on whether the hangers were properly corrected.

This is all the trailing of the engine that is done; the corrections are now calculated from the one set of readings. The errors in the valve rod and the eccentric rod will now be calculated by the effect they have on the port openings. Confusion will be avoided by making the valve-rod calculations first, this to be followed by the eccentric-rod calculations.

132. Calculating Error in Port Openings Due to Valve Rod of Improper Length.—According to Art. 128, the example given in Fig. 50 shows that an error exists in both the valve rod and the eccentric rod. However, the eccentric crank is set correctly, because the sum of the port openings in one gear is equal to the sum of the port openings in the other gear. Now it will be assumed, when taking the port marks, that the distance between them when checked against the steam lap showed that the steam-chest bushings had moved $\frac{1}{8}$

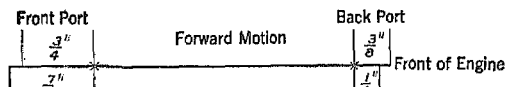

FIG. 51

inch apart, thereby increasing the steam lap and reducing the port openings by this amount. Therefore, this amount will now be added to the port openings given in Fig. 50 at the front port in forward and back gear. This will make the readings appear as if the valve spool was corrected, or as shown in Fig. 51, whereas the correction is not made until later, when all corrections are made at once.

The following rule gives the method of calculating the error in the port openings caused by a valve rod of improper length, as well as the method of determining the direction in which the valve should be moved to correct the port openings.

Rule.—*Add the port openings at the front port, and add the port openings at the back port; subtract the lesser from the greater and divide the remainder by four. If the sum of the openings at the back port exceeds the sum of the openings at the front port,*

move the valve ahead the calculated amount by lengthening the valve rod; if the reverse is true, move the valve back by shortening the valve rod.

The application of this rule to the example in question will result in the following calculations:

$$\tfrac{3}{8}+\tfrac{1}{4}=\tfrac{5}{8} \text{ and } \tfrac{3}{4}+\tfrac{7}{8}=\tfrac{13}{8}$$

Subtract the lesser from the greater Then $\tfrac{13}{8}-\tfrac{5}{8}=1$ inch.
Divide by 4. Then

$$1\div 4=\tfrac{1}{4} \text{ inch.}$$

According to the rule, the valve rod must be shortened $\frac{1}{4}$ inch, and this shortening is done, when all the corrections are made, by turning this amount off the collar. Should the example show that the valve rod requires to be lengthened, a turned washer of the required thickness is applied to the collar. Actually the rod is neither shortened or lengthened; the position of the valve is merely changed on the stem.

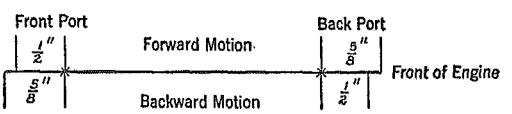

FIG. 52

Sometimes it may be found that the valve is blind at one or more ports. In this event, subtract the amount the port is blind from the opening at the same port in the opposite motion, instead of adding it, and proceed as before.

133. Calculating Error in Port Openings Due to Eccentric Rod of Improper Length.—The original reading after being corrected for the valve-rod error will appear as in Fig. 52, and shows, according to Art. 127, that the eccentric rod requires a correction. The following rule is used to calculate the error in the port openings due to the eccentric rod, as well as to determine the direction in which the valve must be moved to correct the port openings:

Rule.—*Add the port openings diagonally, subtract the lesser from the greater, and divide the result by four. Then, with a direct-motion valve gear, change the length of the rod in the same*

direction that the valve must be moved to correct the forward motion. With an indirect-motion valve gear, change the length of the rod in the direction opposite to that which the valve must be moved to correct the forward motion.

The following calculations will result from the application of this rule:

$$\tfrac{5}{8}+\tfrac{5}{8}=\tfrac{10}{8} \text{ and } \tfrac{1}{2}+\tfrac{1}{2}=1$$

Subtract the lesser from the greater. Then $\frac{10}{8}-1=\frac{1}{4}$.

Divide by 4. Then $\frac{1}{4}\div 4=\frac{1}{16}$ inch, the amount the valve must be moved, by changing the length of the eccentric rod. If it is found that the port openings cannot be squared by the application of the rules already given, an error exists somewhere else than in the valve rod and the eccentric rod. The valve may not be assembled properly, the bushings may have shifted or the valve gear may be distorted at some point.

134. Determining Eccentric-Rod Change.—A change of $\frac{1}{16}$ inch in the length of the eccentric rod does not alter the position of the valve by the same amount because the movement of the rod is more than the travel of the valve. In full gear the eccentric rod usually moves the link foot of the Walschaert valve gear $3\frac{1}{2}$ inches for each inch of valve movement. With the standard Baker gear, the eccentric rod moves the gear connecting-rod 4 inches in moving the valve 1 inch; with the long travel gear, the bottom of the gear connecting-rod moves 3 inches for each inch of valve movement. The expressions $3\frac{1}{2}$ to 1 and 4 to 1 are known as the gear ratio, and always refer to full gear. In shorter cut-offs such as are used when trailing, the gear ratio is not known; hence some method must be used to determine how much the eccentric rod must be changed in order to move the valve some fixed amount, such as $\frac{1}{16}$ inch. The following explains one method that can be employed:

Scribe a line *a*, Fig. 53, on the link foot or the gear connecting-rod with tram 2, using point *b* as a center. At the same time scribe a mark on the valve stem with the valve tram. Now replace the pin in the front end of the eccentric rod with a temporary bolt that is smaller in diameter than the pin, and

long enough to take washers and a nut. Tighten the temporary bolt enough to clamp the jaw of the eccentric rod on the link tail but still permit movement of the link on the small bolt. Next, tap the link tail ahead until the valve tram will scribe a mark $\frac{1}{16}$ inch back of the mark scribed on the valve stem with the eccentric-rod pin in place. Again, with the tram 2 in the same center *b*, scribe a new arc *c* on the tail of the link. The distance between the marks *a* and *c* is the amount the eccentric rod will have to be lengthened in order to move the valve ahead $\frac{1}{16}$ inch. If this distance is, say, $\frac{3}{8}$ inch, since the valve was moved $\frac{1}{16}$ inch, the ratio must be $\frac{3}{8}$ to $\frac{1}{16}$, or 6 to 1. Hence, in the example given in Fig. 52 the eccentric rod will have to be lengthened $\frac{1}{16} \times 6$ or $\frac{3}{8}$ inch, or in the same direction that the valve must be moved to correct the forward motion, a direct-motion valve gear being assumed. It will be noted that the back port is opened the wider, hence the valve must be moved ahead.

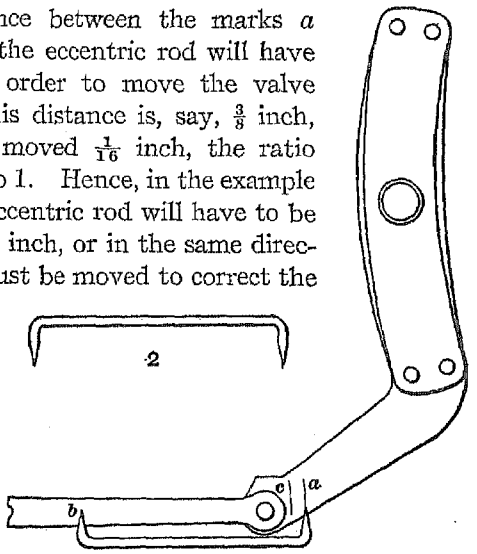

FIG. 53

135. With any single eccentric valve gear the movement of the eccentric rod is in the same direction as the valve in one motion and in the opposite direction in the other motion, so that the effect of a change in the length of the eccentric rod is to shift the valve in one direction in forward motion and in the opposite direction the same amount in backward motion. Therefore, with the greater opening at the back port in forward motion and at the front port in backward motion, as in Fig. 52, lengthening the eccentric rod a sufficient amount or $\frac{3}{8}$ inch to move the valve $\frac{1}{16}$ inch ahead will not only correct the error in forward motion but will also correct the error in backward motion as well.

The valve-rod readings will now appear as shown in Fig. 54, in which the port openings will be equal to $\frac{9}{16}$ inch in both motions.

A correction of $\frac{1}{8}$ inch is now made on the valve spool for the movement of the bushings, the valve rod is shortened $\frac{1}{4}$ by turning this amount of the collar, and the eccentric rod is lengthened $\frac{3}{8}$ inch, thus moving the valve $\frac{1}{16}$ inch.

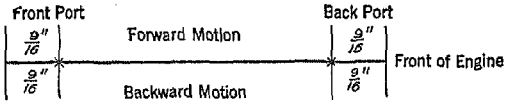

FIG. 54

It will be recalled that, when beginning the work, the radius-rod hangers or gear reach rods were adjusted to obtain a still valve. Therefore after the eccentric rods and valve rods have been corrected, equal port openings in the cut-off selected should be obtained on both sides, it being assumed that both eccentric cranks are set correctly.

136. Explanation of Rules.—The rules given in Articles 132 and 133 determine the average difference in the port openings for both gears. When calculating the average difference it is necessary to add the two greater port openings, next subtract from the result the sum of the two lesser port openings, and divide by the number of port openings, or by four.

With a valve-rod error, the greater port openings will be at the same port in both gears and the lesser at the other port; hence the port openings as arranged in Fig. 45 must be added vertically to obtain the sum of the greater and lesser port openings.

With an eccentric-rod error, the greater port openings will be at one port in one gear and at the opposite port in the other gear, so that the port openings when arranged as in Fig. 46 must be added diagonally in order to find the sum of the greater and lesser openings.

With an eccentric-crank error, the greater port openings will be at the front and back ports in one gear and the lesser

at these ports in the other gear. This is the reason why the port openings must be added horizontally.

SQUARING THE VALVES WITH CORRECTIONS REQUIRED IN VALVE ROD, ECCENTRIC ROD, AND ECCENTRIC CRANK

137. Eccentric Crank.—It has already been mentioned that no account is ordinarily taken of the eccentric crank when the valves are set by the trailing method. With the exception of rare cases, the crank will be found to be set correctly and the valves can be squared by making the required alterations in the valve rod and the eccentric rod. However, it is sometimes found that the eccentric crank is far enough out of its correct position to make it difficult to square the valves; hence a discussion is desirable that will enable a valve setter to recognize and correct errors introduced in the valve readings by an improperly set crank. This will be prefaced by an explanation of the factor that governs the position of this crank.

138. Center Line of Motion of Eccentric Rod.—A fundamental requirement in the design of the Walschaert valve gear is that the position of the eccentric crankpin and the length of the eccentric rod must be such that, when the main crankpin is on either dead center, the link will be in a central position. The link is said to be in such a position when the arc scribed by the radius rod conforms with the link arc; hence there will be no movement imparted to the valve when the radius rod and the link block are raised and lowered by the reverse lever. To bring the link to a central position when the engine is on a dead center, the eccentric crank must be set at 90 degrees to the center line of motion of the eccentric rod, which, as shown in Fig. 55, is a line drawn through the center of the main axle and the eccentric-rod pin in the link foot when the link is central. With the Baker valve gear, the center line of motion of the eccentric rod, Fig. 56, is a line drawn through the center of the main axle and the center of the eccentric-rod pin in the gear connecting-rod when this rod is in its central position. The gear connecting-rod is in its central position when the main crankpin is on either dead center.

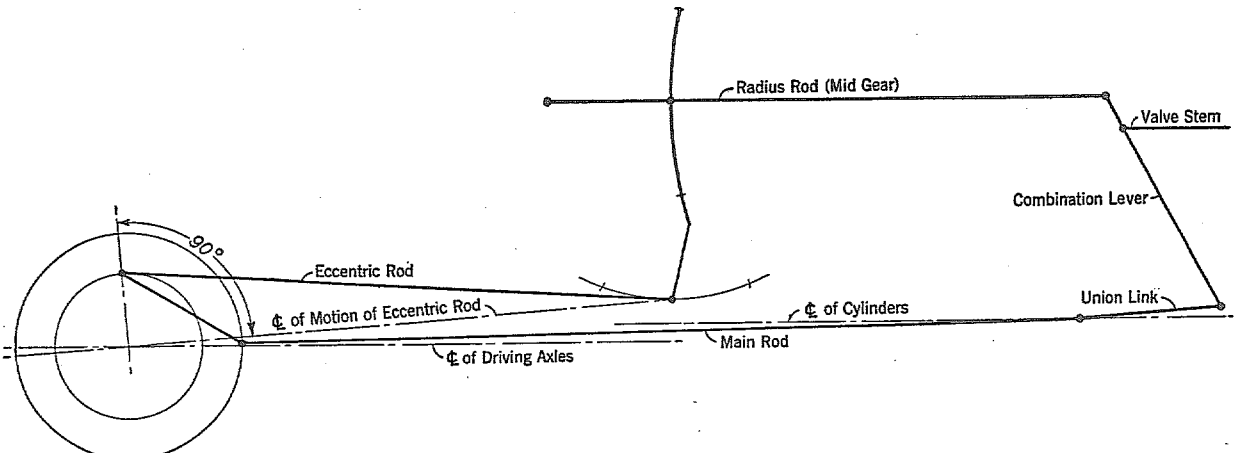
Radius Rod (Mid Gear)
Valve Stem
Combination Lever
90°
Eccentric Rod
℄ of Motion of Eccentric Rod
℄ of Cylinders
Union Link
Main Rod
℄ of Driving Axles

FIG. 55

139. Correct Position of Eccentric Crank.—The eccentric crank to be set correctly must meet two requirements. First, it must be located at an angle of 90 degrees to the center line of motion of the eccentric rod; second, the diameter of the circle scribed by the crank must agree with the erecting print. The first requirement insures that the valve will move an equal distance on each side of its mid-position and thus give approximately equal port openings in both gears; provided the angularity of the eccentric rod is compensated for; the second insures that the travel of the valve is in accordance with the design.

Should the center line of motion of the eccentric rod lie on the same line as the center line, Fig. 55, of the axles, the crank would be set at an angle of 90 degrees to the main crank. The eccentric-rod pin in the link foot or gear connecting-rod is always placed above the center line of the axles so as to prevent an undue lengthening of these parts, which condition would necessitate an eccentric crank of a greater throw.

140. Setting Eccentric Crank.—The eccentric crank can be set square with the center line of motion only when the dead center method of valve setting is employed. The crank is first given a temporary setting by the gauge shown in Fig. 11, which merely sets the crank to scribe the circle specified in the print; afterward the crank is set square with the center line of motion by the method explained in Art. 47, which involves taking the dead centers.

The dead centers cannot be obtained when the trailing method of valve setting is used; hence all that can be done is to set the eccentric crank by the gauge. Setting the crank by the gauge does not imply that the crank is set at 90 degrees to the center line of motion unless the engine conforms in all particulars to the erecting print. Ordinarily, when set to the correct crank circle, a small adjustment is necessary to locate the eccentric crank properly with respect to the center line of motion. The reason is that the center line of motion lowers under service conditions when the engine settles on its springs; hence the link foot lowers and the angle between the center

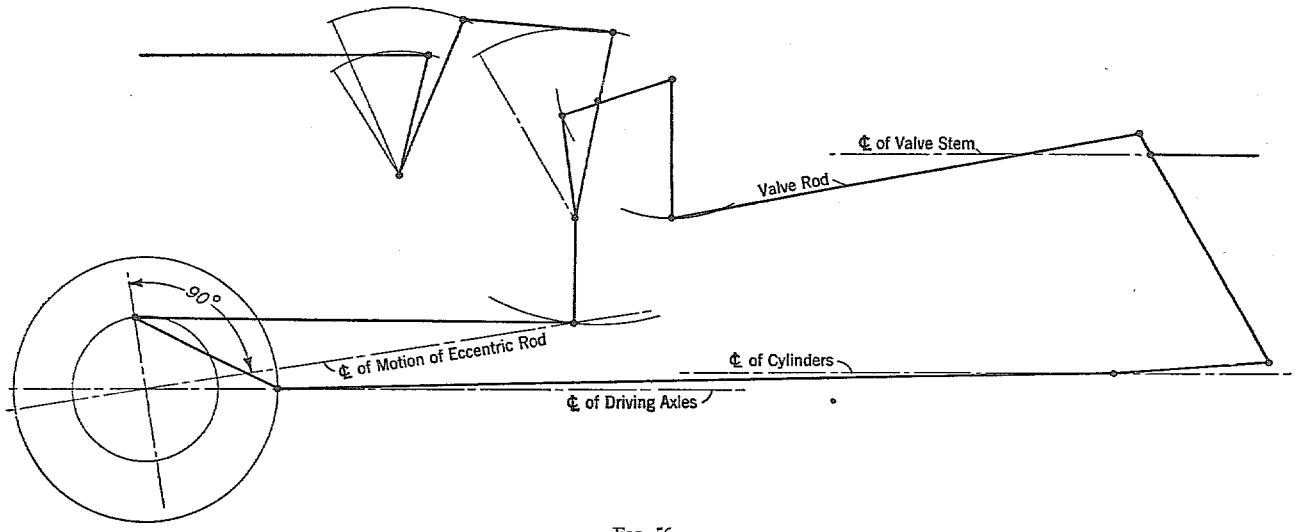
℄ of Valve Stem
Valve Rod
90°
℄ of Motion of Eccentric Rod
℄ of Cylinders
℄ of Driving Axles

FIG. 56

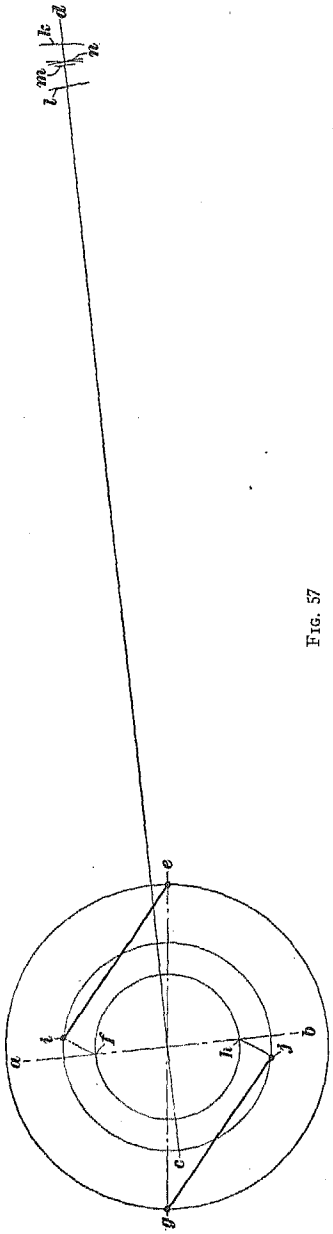

FIG. 57

line of motion of the eccentric rod and the eccentric crank, increases. If the eccentric crank is then adjusted to a 90-degree position, the diameter of the eccentric crank circle and hence the valve travel will vary somewhat from the print. However, this is of less importance than an error in setting the crank square with the center line of motion.

141. The following gives the principle involved in the procedure outlined in Art. 47, when locating the eccentric crank at 90 degrees to the center line of motion of the eccentric rod.

In Fig. 57 the line *ab* is at right angles to the center line of motion *cd* of the eccentric rod. The correct position of the eccentric-crank pin with the engine on the forward dead center *e* is then at *f* and when on the back dead center *g* the pin should be at *h*. Instead the eccentric-crank pin is at *i* on one dead center and at *j* on the other dead center. Now the eccentric crank can be brought to a right-angle position with the center line of motion by first placing a point of a long tram at *i* and scribing a line *k* on a piece of plate in line with

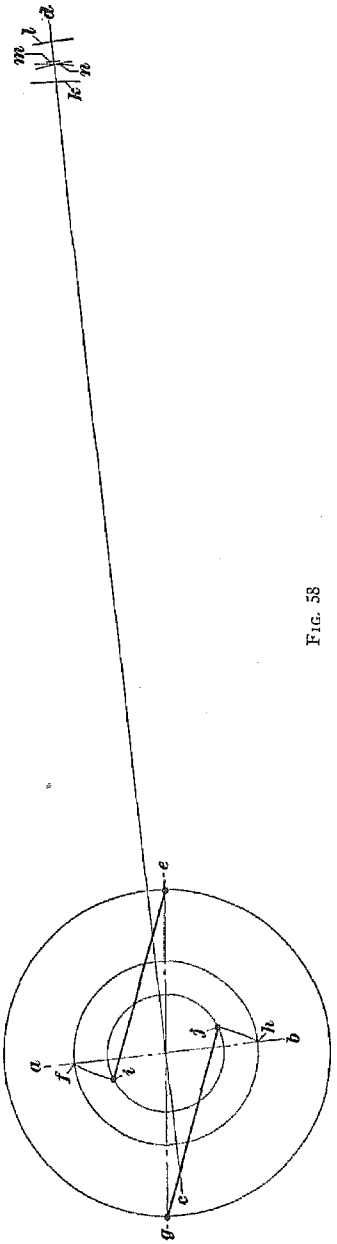

FIG. 58

the eccentric rod, with the engine on the front dead center, and next scribing a line *l* with the tram point at *j* with the engine on the back dead center. The tram should be of about the same length as the eccentric rod and should be held at about the same angle. The distance between *k* and *l* represents twice the amount the crank is displaced in a straight line from the line *ab*. If the tram point is placed on the point *m* midway between *k* and *l* and the eccentric crank is driven in until the other point of the tram registers with the point *i* it will be found that this point will almost coincide with the point *f*, the true position of the eccentric crank. Actually the tram point must be placed at *n* slightly ahead of the mid-position to insure bringing the eccentric crank to *f*. This refers to a case where the crank has to be driven in or towards the center of the axle. When driven out or away from the axle center as in Fig. 58, the point *n* comes slightly back of the mid-position point. The operation described in Art. 49 is based on the foregoing, the mid-position point, however, being the one that is considered in this Article.

CALCULATIONS INVOLVING POSITIVE AND NEGATIVE QUANTITIES

142. Rules to Be Followed.—When adjustments are necessary in the valve rod, the eccentric rod, and the eccentric crank, the readings obtained on the valve rod when the engine is trailed will often indicate that the valve fails to open the steam edge of one or more ports. In this event the valve or the port is usually referred to as being blind. When calculating the corrections, the amount the port is closed is considered as a negative number or a minus quantity, and is indicated by a minus sign, whereas if the port is open, the extent of the opening is taken as a positive or a plus quantity and is indicated by a plus sign. The addition and subtraction of positive and negative quantities depend on algebraic principles which are beyond the scope of this lesson paper; hence rules will be given to show how the calculations are to be performed.

143. Addition of a Positive and a Negative Fraction. When adding a positive and a negative fraction, subtract the lesser from the greater, remembering that the sign before the larger number is to be placed before the result. When the sign before the result is positive, the plus sign is omitted. Thus,

$$(+\tfrac{3}{32})+(-\tfrac{1}{16})=\tfrac{1}{32},\ (+\tfrac{5}{8})+(-\tfrac{3}{8})=\tfrac{1}{4}$$

144. Addition of Two Negative Fractions.—When adding two negative fractions, proceed as in addition, remembering that the result will be negative. Thus,

$$(-\tfrac{3}{32})+(-\tfrac{1}{16})=-\tfrac{5}{32},\ (-\tfrac{5}{16})+(-\tfrac{1}{32})=-\tfrac{11}{32}$$

145. Subtraction of a Negative Fraction From a Positive Fraction.—The rule in this case is to consider the negative fraction as being positive, and proceed as in addition. Thus,

$$(+\tfrac{3}{32})-(-\tfrac{1}{16})=+\tfrac{5}{32},\ (+\tfrac{7}{8})-(-\tfrac{1}{8})=\tfrac{8}{8}\text{ or }1$$

EXAMPLES OF ERRORS IN VALVE GEAR INVOLVING POSITIVE AND NEGATIVE QUANTITIES

146. Condition Assumed.—Let it be assumed that the readings obtained on the valve rod when the engine is trailed is as shown in Fig. 59, in which the valve has the front port closed $\frac{9}{32}$ inch and the back port open $1\frac{7}{32}$ inch in forward motion. In backward motion both ports are blind, the back port $\frac{3}{32}$ inch and the front port $\frac{7}{32}$ inch.

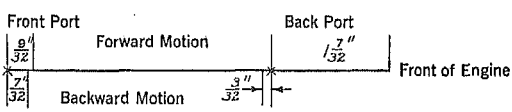

FIG 59

This is an abnormal condition that will seldom be met with in practice but affords a good example of the calculations necessary when positive and negative port openings are encountered.

According to Art. 130, the readings show errors in the valve rod and the eccentric rod, as well as in the setting of the eccentric crank. The corrections to be made in these parts will all be calculated from the readings shown in Fig. 59, the engine being trailed only once.

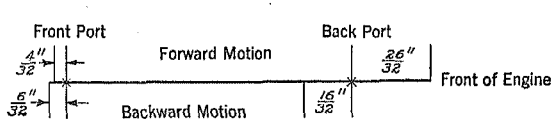

FIG. 60

147. Calculating Error Due to Valve Rod.—The valve-rod error will be calculated first from the rule given in Art. 132. The application of this rule will result in the following calculations:

$$(+\tfrac{30}{32})+(-\tfrac{3}{32})=+\tfrac{26}{32} \text{ and } (-\tfrac{9}{32})+(-\tfrac{7}{32})=-\tfrac{16}{32}$$

Subtract the lesser from the greater, in which case the numbers must be added. See Art. 145. $(+\frac{26}{32})-(-\frac{16}{32})=+\frac{52}{32}$

Divide by 4. $\frac{52}{32}\div 4=\frac{13}{32}$

The valve rod must then be lengthened $\frac{13}{32}$ inch because the sum of the openings at the front port are less than those at the back port, hence the valve must be moved ahead. Moving the valve ahead $\frac{13}{32}$ inch will result in an opening at the front port, forward motion of $\frac{13}{32}$ less $\frac{9}{32}$, or $\frac{4}{32}$ inch, and will reduce the opening at the back port to $1\frac{7}{32}-\frac{13}{32}$, or to $\frac{26}{32}$ inch. In backward motion, the opening at the front port will equal $\frac{13}{32}$ less $\frac{7}{32}$, or $\frac{6}{32}$, and at the back port, the valve will be blind $-\frac{3}{32}-\frac{13}{32}$, or $-\frac{16}{32}$. The original readings will then appear as in Fig. 60.

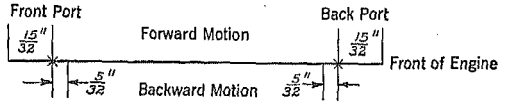

FIG. 61

148. Calculating Error Due to Eccentric Rod.—The eccentric-rod correction will be calculated next by applying the rule given in Art. 133. The application of this rule to the valve-rod readings so far obtained will result in the following calculations:

$$(\tfrac{26}{32})+(\tfrac{6}{32})=\tfrac{32}{32}$$

and

$$(-\tfrac{16}{32})+(+\tfrac{4}{32})=-\tfrac{12}{32}$$

Subtract the lesser from the greater. $(+\frac{32}{32})-(-\frac{12}{32})=+\frac{44}{32}$

Divide by 4. $\frac{44}{32}\div 4=\frac{11}{32}$

As the opening at the back port is more than at the front port in forward motion and as the gear is assumed to be direct when going ahead, the valve must be moved forward; hence, the eccentric rod must be lengthened an amount, as explained in Art. 134, that will result in the valve being moved ahead $\frac{11}{32}$ inch. Adding $\frac{11}{32}$ to $\frac{4}{32}$ and subtracting $\frac{11}{32}$ from $\frac{26}{32}$ will leave port openings of $\frac{15}{32}$ inch at both ports in forward motion. In backward motion, as the link block is now in the upper half of the link, the lengthening of the eccentric rod will subtract $\frac{11}{32}$ from the $\frac{6}{32}$ opening at the front port and will leave this port $\frac{5}{32}$ inch blind, and when added to the $\frac{16}{32}$ the amount the

back port is blind will leave this port $\frac{5}{32}$ inch blind. The readings will now appear as in Fig. 61.

149. Calculating Error Caused by Improperly Set Eccentric Crank.—According to Art. 129 the readings given in Fig. 61 indicate that the eccentric crank is not set properly because the sum of the port openings at the front and back ports in forward gear is not equal to the sum of these port openings in back gear. The correction to be made at the valve when the eccentric crank is set improperly can be calculated from the following rule:

Rule.—*Add the port openings in the forward motion and the port openings in the backward motion, subtract the lesser from the greater, and divide by four.*

Thus, $(\frac{15}{32})+(\frac{15}{32})=\frac{30}{32}$ and $(-\frac{5}{32})+(-\frac{5}{32})=-\frac{10}{32}$

Subtract the lesser from the greater. $(+\frac{30}{32})-(-\frac{10}{32})=\frac{40}{32}$

Divide by 4. $\frac{40}{32}\div 4=\frac{10}{32}$

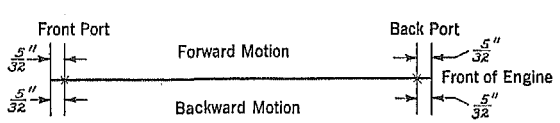

FIG. 62

150. The position of the eccentric crank may be corrected either before or after the required alterations are made in the eccentric rod and the valve rod. The correction requires the eccentric crank to be driven in until a tram held on the valve rod shows that it has moved $\frac{10}{32}$ inch. The reading will then appear as in Fig. 62.

When shifting the position of the eccentric crank, the main crankpin should be placed either on or near the bottom forward eighth or the top back eighth, because it is in these positions that a movement of the eccentric crank will have the greatest effect on moving the valve and the least on the eccentric crank circle.

The view of the Walschaert valve gear in Fig. 63 will serve to illustrate the direction in which an eccentric crank should be

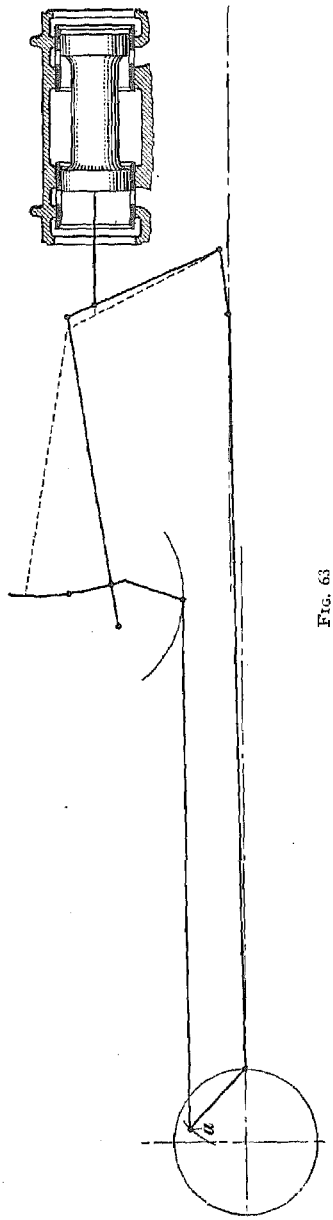

Fig. 63

driven when the port openings in one gear are not equal to the port openings in the other gear. If the center of the eccentric crank *a* is too far from the center of the axle, the bottom of the link will be pushed forward, thus increasing the port opening at the front port, as well as at the back port in forward motion. In backward motion, the upper part of the link will be to the left of its true position; hence the port openings in backward motion will be reduced by the same amount that the openings in forward motion were increased. In other words, the link reverses the error in the setting of the eccentric crank when the engine is reversed. The eccentric crank must then be driven in toward the axle when the port openings in forward gear exceed those in back gear, provided the motion is direct in forward gear. If the port openings in forward gear are less than in back gear, the crank must be driven out.

If the motion is indirect in forward gear, and the port openings are greater in this gear than in backward gear, the eccentric crank must be driven out, and if the port openings are less in forward gear the crank must be driven in or toward the center of the axle.

SETTING VALVES OF THREE-CYLINDER LOCOMOTIVES

151. With three-cylinder locomotives the outside valves are set in the same manner as with two-cylinder locomotives. The readings of the inside valve are taken at the same time as the outside valves. The valve stem extension is provided with a bracket on which the port marks are scribed; the peep hole plugs on the inside steam chest are located near the under side where the ends project beyond the casting.

After the outside valves have been set properly and all necessary changes made, the readings of the inside valve are taken and analyzed. The corrections are made by shortening or lengthening the valve stem by washers; no other adjustments being possible.

If the indications are that the valve has to be moved ahead $\frac{1}{16}$ inch to equalize the lead, a washer of this thickness must be removed from between the end of any valve stem and its extension. If the valve has to be moved back any certain amount then a washer of an equal thickness is applied to any one of the valve stems, or if desired the correction may be made at all three valve stems by alloting one-third to each. There is no preference as to the stem to which the washer should be applied to or taken from except that about the same number of washers should be on each stem.

If at any time an alteration is made in either or both of the outside gears, the setting of the inside valve will also be affected and it will have to be reset. However, a change at the inside valve does not affect the outside gears.

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